

# **White spot lesions during multibracket appliance treatment – a challenge for clinical excellence**

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Tag der Disputation: 30.05.2011

## Dedication

This thesis would be incomplete without mentioning my great father Naeem Enaia and my wonderful mother Nagbegah, who have supported me all the way since the beginning of my studies. It dedicates to my brother Mohamed Enaia and my three sisters Reham, Rana, Role. It is also dedicated to Hannah and everyone, who has been a source of motivation and inspiration.

## Declaration

„Ich erkläre: ich habe die vorgelegte Dissertation selbständig, ohne unerlaubte fremde Hilfe und nur mit den Hilfen angefertigt, die ich in der Dissertation angegeben habe. Alle Textstellen, die wörtlich oder sinngemäß aus veröffentlichten oder nicht veröffentlichten Schriften entnommen sind, und alle Angaben, die auf mündlichen Auskünften beruhen, sind als solche kenntlich gemacht. Bei den von mir durchgeführten und in der Dissertation erwähnten Untersuchungen habe ich die Grundsätze guter wissenschaftlicher Praxis, wie sie in der „Satzung der Justus-Liebig-Universität-Giessen zur Sicherung guter wissenschaftlicher Praxis“ niedergelegt sind, eingehalten.“

# Table of contents

<b>1</b>	<b>INTRODUCTION.....</b>	<b>1</b>
<b>2</b>	<b>AIM.....</b>	<b>4</b>
<b>3</b>	<b>MATERIALS UND METHODS .....</b>	<b>5</b>
<b>4</b>	<b>RESULTS.....</b>	<b>21</b>
<b>5</b>	<b>DISCUSSION .....</b>	<b>77</b>
<b>6</b>	<b>CONCLUSION.....</b>	<b>92</b>
<b>7</b>	<b>SUMMARY .....</b>	<b>93</b>
<b>8</b>	<b>ZUSAMMENFASSUNG .....</b>	<b>95</b>
<b>9</b>	<b>REFERENCES.....</b>	<b>97</b>
<b>10</b>	<b>ATTACHMENT.....</b>	<b>107</b>
<b>11</b>	<b>PUBLICATION.....</b>	<b>108</b>
<b>12</b>	<b>ACKNOWLEDGEMENT .....</b>	<b>113</b>
<b>13</b>	<b>CV.....</b>	<b>114</b>

## 1 INTRODUCTION

Labial surface demineralisations (“White Spots”) are one of the most undesired iatrogenic side effects during orthodontic treatments using multibracket appliances (MB) (Figure 1.1) that have been reported to occur in 2-96% of the MB-patients (*Gorelick et al., 1982; Mizrahi, 1982; Artun und Brobakken, 1986; Geiger et al., 1988; Mitchell, 1992; Wenderoth et al., 1999; Pancherz et al., 1997; Fornell et al., 2002; Lovrov et al., 2007*). Thus, patients receiving MB-treatment are significantly more susceptible to the development of WSL than untreated patients (*Øgaard, 1989*).



**Figure 1.1** White Spot Lesions specially on the upper incisors after removal of a multibracket appliance.

The presence of brackets, bands and archwires impairs oral hygiene measures and increases the plaque retention sites (*Mizrahi, 1982; Gorelick et al., 1982; Årtun and Thylstrup, 1989; Chang et al., 1997; Øgaard et al., 1988; Øgaard, 2001*). As a result of increased plaque accumulation the level of caries inducing bacteria in the oral cavity such as *S. mutans* will be elevated (*Balenseifien and Madonia, 1970; Diamandi-Kiopiotti et al., 1987; Boyar et al.,*

1989). The consequently lower pH of the retained plaque on the enamel surface adjacent to orthodontic brackets hinders the remineralization process and decalcification can occur (*Chatterjee and Kleinberg, 1979; Gwinnett and Ceen, 1979*). Initial enamel decalcifications can be seen as early as 4 weeks after the beginning of a MB-treatment (*O'Reilly and Featherstone, 1987; Øgaard et al., 1988*).

In the early stages, caries appears as opaque milky white stripes or spots and may increase in severity presenting cavitation (*Fehr et al., 1970; Gorelick et al., 1982; Artun and Thylstrup, 1986*). The opaque white spot appearance is caused by changes in the optical properties of the enamel due to subsurface demineralization (*Fehr et al., 1970*). White spot lesions may stop its development after removal of MB-appliances because the cariogenic challenge has ceased (*Artun and Thylstrup, 1986*). In addition, such inactive incipient carious lesions may regress and become less prominent (*Backer Dirks, 1966; Fehr et al., 1970; Artun and Thylstrup, 1986*). However, they may remain esthetically unpleasant particularly if they are extensive (*Artun and Thylstrup, 1986*).

Nevertheless, not every white discoloration on an enamel surface has to be a carious WSL, it can also occur as a result of dental fluorosis or traumatic lesions. An accurate differential diagnosis of the different types of white tooth discolorations can be sometimes challenging. Dental fluorosis can be differentiated from other nonfluoride opacities as they are white/yellowish lesions not well defined and having symmetrical distribution in the mouth, which is independent from the localization of orthodontic brackets. Nonfluoride traumatic opacities have a more defined shape, random distribution and are often located in the middle of the tooth (*Russell, 1961*). On the other hand, WSL are milky white opacities that are mostly seen around the periphery of the bracket base or directly underneath the archwire (*Summitt, 2006*).

Although it is generally accepted, that fluoride reduces the rate of demineralization. Fluoride treatment has a limited effect under bacterially produced lower pH conditions (*Rølla and Øgaard, 1993*) as they occur in MB-patients compared to untreated individuals (*Chatterjee and Kleinberg, 1979*) as a result of the above mentioned plaque retentive properties of MB-appliances.

Many prophylactic measures have been introduced in the last decades aiming at the prevention of WSL during MB-treatment. Among the most common and effective measures are special oral hygiene instructions including a recommendation for the use of high fluoride toothpaste (*D'Agostino et al., 1988; Alexander and Ripa, 2000*), fluoride mouthrinse and high fluoride content products. The demineralization-inhibiting tendency of a daily use of fluoride rinse has been shown during MB-therapy (*Benson et al., 2004; Shafi, 2008*). While specific orthodontic efforts like the use of fluoride releasing bonding materials seem to have minimal or no positive effect (*Derks et al., 2004*).

The above mentioned general prophylactic measures have been in use in the Department of Orthodontics at the University of Giessen since 1996. It is thus, the aim to assess the prevalence and incidence of WSL in MB-patients under standard instructive and general fluoride prophylactic measure condition in order to generate a baseline dataset for future comparison.

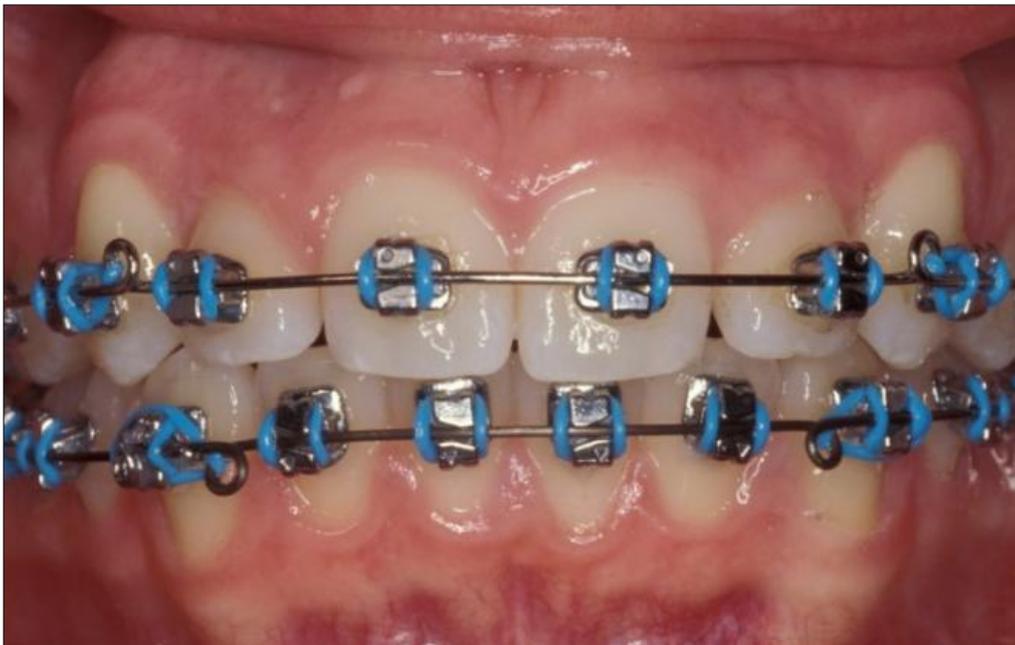
## 2 AIM

This study aimed to investigate the incidence and further course of white spot lesions during multibracket appliance treatment and its relation with gingival inflammation.

### 3 MATERIALS AND METHODS

#### 3.1 Study Population

Ethic approval for the present study was granted by the Ethical Committee of Medical Faculty of the Justus-Liebig-University, Giessen (approval number 112/09). The treatment records of all patients that had completed a MB-appliance treatment (Figure 3.1.1) within the period 1996 – 2006 at the Department of Orthodontics of the Justus-Liebig-University in Giessen were retrospectively screened for inclusion.



**Figure 3.1.1** Intraoral frontal view of a patient with full upper and lower jaw MB-appliance.

The following inclusion criteria were applied:

1. no previous MB-treatment,
2. all four upper front teeth (UFT = any tooth present in the area 12-22) should be fully erupted and fully visible before the start of treatment,
3. no dental structural abnormalities or frontal fillings, veneers or other type of reconstructions present on the four UFT neither before nor after treatment,
4. at least four brackets bonded to the UFT,

5. MB-treatment for at least one year,
6. retention period for at least one year,
7. full available documentation (treatment charts, intraoral slides) before treatment (T0), after MB-treatment (T1) and after retention (T2),
8. before treatment slides less than one year old (Mean = 0.36 years / SD 0.26)
9. after treatment slides taken directly or at the latest within a week of bracket debonding (Mean = 0.32 days / SD 0.56)

At start of MB-treatment all patients received general oral hygiene instructions and special MB cleaning instructions including a recommendation (1) for the daily use of fluoride toothpaste and fluoride mouthrinse and (2) the weekly use of high fluoride content products.

The first 400 (168 male, 232 female) patients meeting the inclusion criteria were included in the study. All four UFT could be assessed in every patient, thus resulting in the evaluation of 1600 teeth. The average age of the patients was 13.7 years (SD 3.5 / range 8.7 - 40.3 yrs) before treatment (T0), 15.7 years (SD 3.6 / ranged 10.3 - 43.1 yrs) after treatment (T1) and 17.7 years (SD 3.6 / range 12.3 - 45.3 yrs) after retention (T2). Active treatment time was on average 1.9 years (SD 0.76) with an upper limit of 7.5 years, while the average retention time amounted to 2 years with a maximum of 6.1 years.

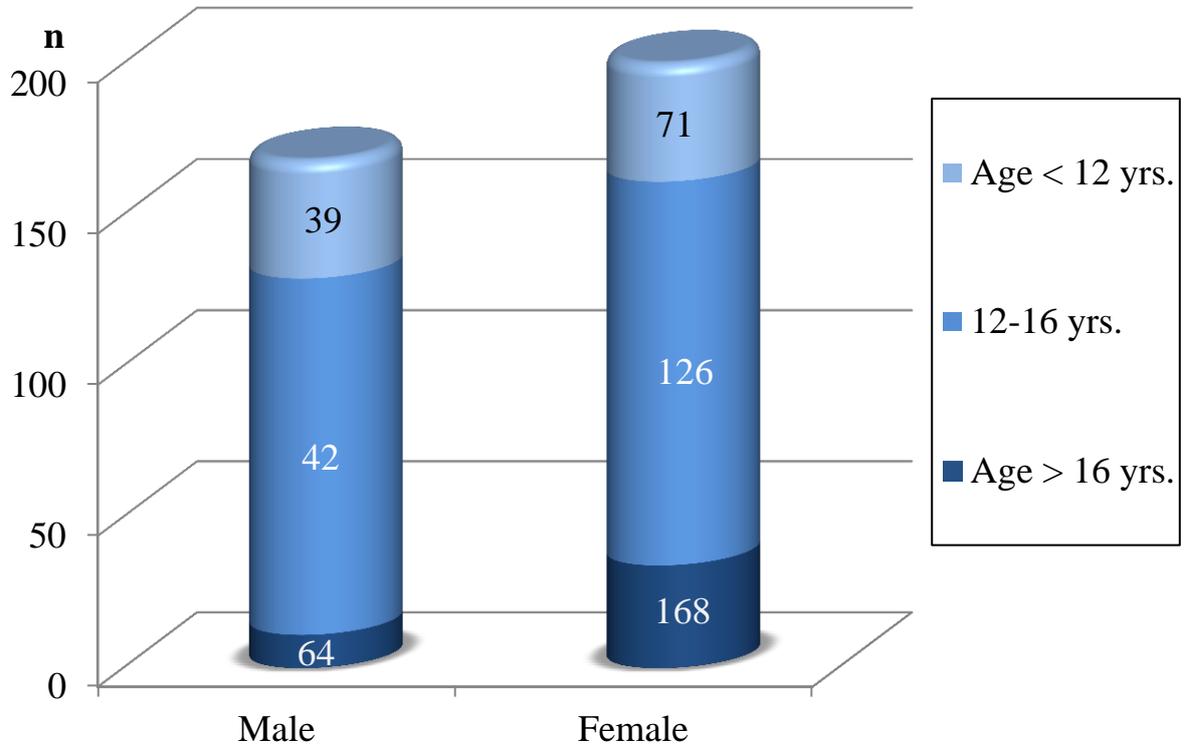
Based on the patients' age before treatment (T0), the patients were distributed into three age groups as it is demonstrated in Table 3.1.1 and Figure 3.1.2.

Age groups at (T0):

- Age < 12 years
- 12-16 years
- Age > 16 years

**Table 3.1.1** Distribution of the 400 MB-patients according to gender and the three before treatment age groups. The number of patients (n), the percentage of patients from the total 400 patients (Total Pct), the percentage of patients per row (Row Pct) and the percentage of patients per column (Col Pct) are given.

Age group Gender	Age < 12 yrs.	12-16 yrs.	Age > 16 yrs.	Total
<b>Male</b>	n = 39 9.7% Total Pct 23.2% Row Pct 35.4% Col Pct	n = 118 29.5% Total Pct 70.2% Row Pct 48.2% Col Pct	n = 11 2.7% Total Pct 6.5% Row Pct 24.4% Col Pct	n = 168 42% Total Pct
<b>Female</b>	n = 71 17.7% Total Pct 30.6% Row Pct 64.5% Col Pct	n = 127 31.7% Total Pct 54.7% Row Pct 51.8% Col Pct	n = 34 8.5% Total Pct 14.7% Row Pct 75.6% Col Pct	n = 232 58% Total Pct
<b>Total</b>	n = 110 27.5% Total Pct	n = 245 61.2% Total Pct	n = 45 11.2% Total Pct	n = 400 100%



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**Figure 3.1.2** Distribution (n) of the 400 MB-patients according to gender and the three before treatment age groups.

## 3.2 Methods

### Case documentary sheets

A case documentary sheet (see attachment) was developed in order to facilitate patients' data registration. It comprised of the following three parts:

#### 1. Personal data

- Subject serial number
- Date of birth
- Gender

#### 2. Treatment data

- Date of treatment beginning (MB-in)
- Date of treatment end (MB-out)
- Date of last photographic documentation

#### 3. Slide examination and data

##### -Before treatment (T0):

Date slides were taken

Evaluation of the four UFT using a modified WSL-Index

Examination of gingival inflammation

##### -After treatment (T1):

Date slides were taken

Evaluation of the four upper UFT using a modified WSL-Index

##### -After retention (T2):

Date slides were taken

WSL change-Index used for evaluation of the four UFT

Examination of gingival inflammation

### Slide examination data

All examined slides were taken by the same photographer in a standardized technique using an Olympus (OM-4 TI) Camera with a Macro Objective (80mm) supplied by a ring flash (Olympus T 10) and Kodak Ektachrome Pro Colour reversal films. The slides of three different time points of the treatment (T0, T1, T2) were assessed retrospectively. At each time point three standardized intraoral slides (Figure 3.2.1) were used to assess the four UFT.



Before treatment (T0)



After treatment (T1)

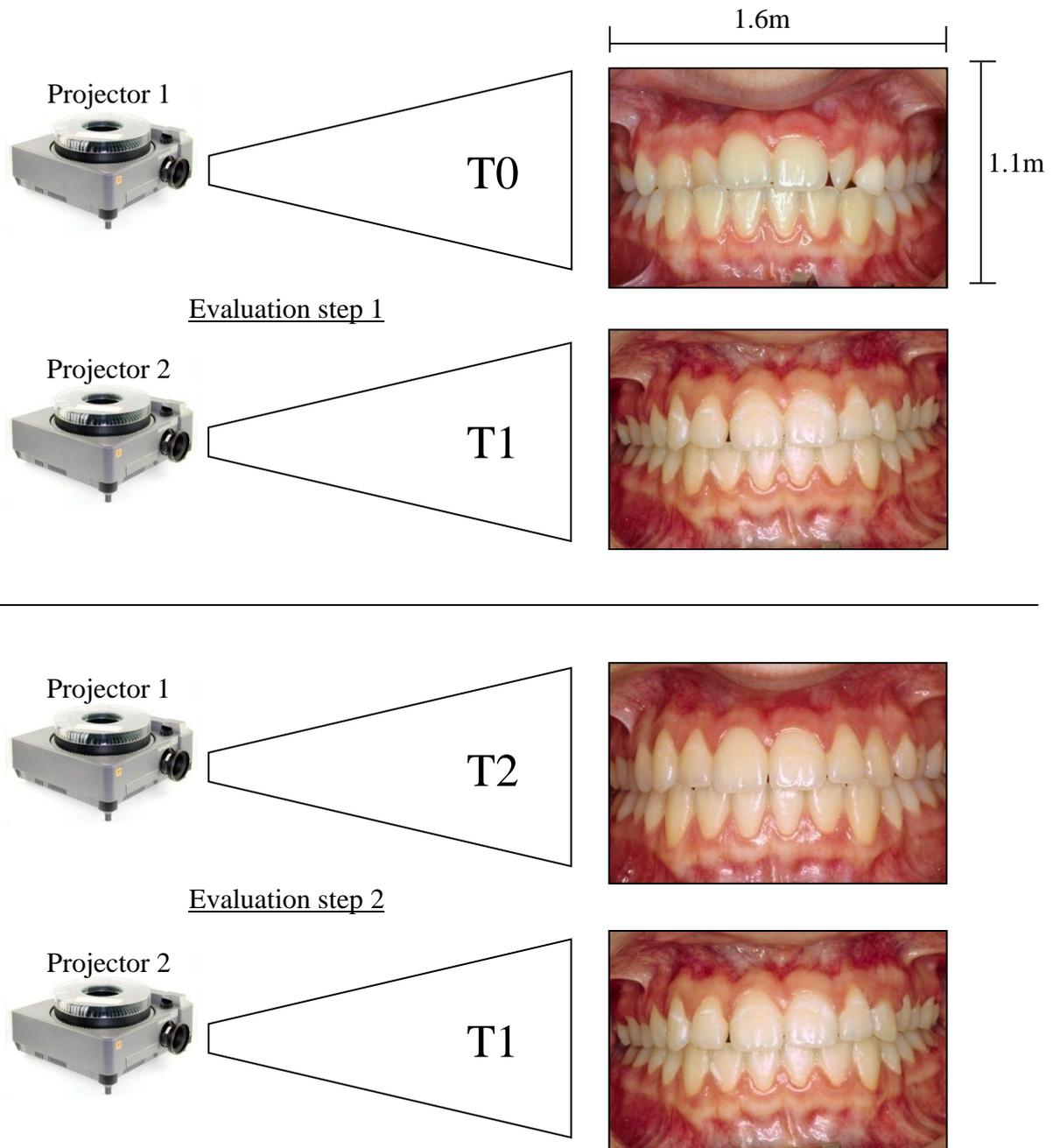


After retention (T2)

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**Figure 3.2.1** Standardized documentary intraoral photographic slides from patients' treatment records at the different treatment time points.

Visual assessment of the slides was done using two Kodak Ektapro 500 Slide projectors and a projective size of 1.1m x 1.6m per image. In each evaluation's step, two different time points T0 and T1 and thereafter T1 and T2 were projected and evaluated simultaneously as shown in Figure 3.2.2.

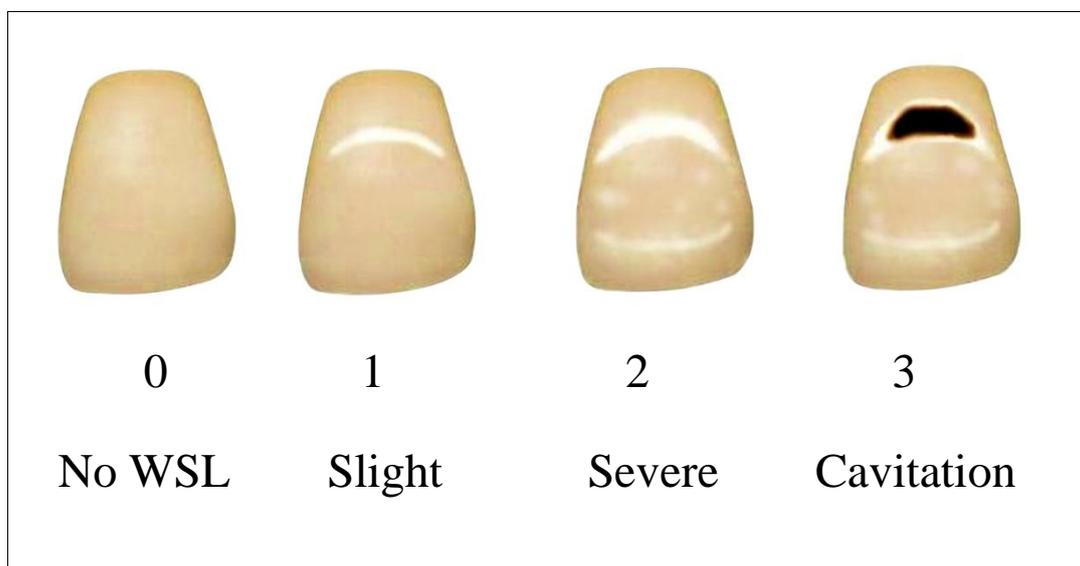


**Figure 3.2.2** Demonstration of the two evaluations' steps (T0-T1) and (T1-T2). The projective size of 1.1m x 1.6m per image is indicated.

### 3.3 Study Parameters

#### White Spots Lesion-Index (T0, T1)

A modified White spot lesion index (WSL-Index) by Gorelick et al. (1982) was used to evaluate the four UFT before (T0) and after treatment (T1). The visual slide evaluation of the individual teeth was based on a labial surface examination assessing the presence or absence of WSL. The severity of WSL was scored as follows (Figure 3.3.1).



**Figure 3.3.1** Schematic representation of the scoring degrees according to the modified WSL-Index by Gorelick et al. (1982). The WSL severity scores were: (0) = no white spot lesion formation, (1) = slight white spot or line formation, (2) = excessive white spot formation, (3) = white spot formation with cavitations.

At T0 and T1 patients were divided into four groups depending on the highest WSL score that could be assessed from one or more of the four UFT:

- No WSL patients group
- Slight WSL patients group
- Severe WSL patients group
- Cavitations patients group

## White Spots Lesion Change-Index (T1-T2)

Assessment of the further course of WSL during the retention period was performed using a modified White Spot Lesion Changing Index (WSLC-Index) as described by *Pancherz & Mühlich* (1997). The visual evaluation of the individual teeth was based on a labial surface comparison between the time points after treatment (T1) and after retention (T2). The following scores were given:

- (0) no white spot lesion at any time point during treatment
- (+) improved WSL
- (=) unchanged WSL
- (-) worsened WSL

At T2 patients were divided into four groups depending on the WSL changes:

- No WSL all time patients group: no WSL could be seen on the four UFT at any time (T0, T1 or T2).
- Improved WSL patients group: all WSL on the UFT of a patient improved between T1 and T2.
- Unchanged WSL patients group: one or more of the WSL on the UFT of a patient had remained unchanged while none of the other WSL were worsened between T1 and T2.
- Worsened WSL patients group: one or more of the WSL on the UFT of a patient had worsened. The patients were assigned to this group irrespective of the development of other lesions.

### Gingival inflammation examination

The presence of gingival inflammation was assessed before treatment (T0) and after retention (T2). The visual evaluation of the UFT region aimed at the identification of gingival redness and/or swelling of the gingival margin. The presence of one of these signs on at least one of the four UFT resulted in positive scoring as shown in Figure 3.3.2.

The following scores were given:

- (0) no gingival inflammation (no redness and/or swelling)
- (1) gingival inflammation (redness and/or swelling)



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**Figure 3.3.2** Intraoral frontal views of patients with no gingival inflammation (right), and with gingival inflammation (left).

## Intra-examiner reproducibility and inter-examiner reliability

The records of the first 10 patients from the 400 patients sample were examined simultaneously but independently by three previously calibrated examiners. One week later the session with the same three examiners evaluating the same 10 patients was repeated.

### Intra-examiner reproducibility

The comparison of the WSL scores obtained from each of the three examiners at the two different evaluation sessions was used to calculate the intra-examiner reliability using Fleiss' kappa (*Fleiss, 1971*). For the first examiner (the study examiner, who conducted the whole study evaluations) the T0 and T1 WSL scores showed an agreement of 95.1% between the sessions, while for the T2 scores an agreement of 92.7% was seen. For the second examiner (department head), the T0 and T1 WSL scores showed an inter-session agreement of 92.2%, while for the T2 scores an agreement of 83.5% was seen. For the third examiner, the T0 and T1 WSL scores showed an inter-session agreement of 70.2%, while for the T2 scores an agreement of 47.5% was seen (Table 3.3.1, Table 3.3.2).

### Inter-examiner reliability

The WSL scores from the three different examiners at each evaluation session were used to calculate the inter-examiner reliability by means of a non-parametric test (Kendall's Coefficient of Concordance; *Kendall et al., 1939*). At the first evaluation session, the WSL scores of the three examiners showed an agreement of 75.3% for T0, 83.1% for T1 and 80.1% for T2 (Table 3.3.3). At the second evaluation session, the WSL score agreement was 78.4% for T0 and 82% for both T1 as well as T2 (Table 3.3.4).

**Table 3.3.1** Intra-examiner reproducibility for T0 and T1 WSL scores for the three examiners. The weighted Kappa values, the asymptotic standard errors valve (ASE) and the 95% Confidence limits are given.

Examiner	Fleiss' Kappa	Value	ASE	95% Confidence Limits	
1 <sup>st</sup> Examiner	Weighted Kappa	0.9512	0.0465	0.8601	1.0000
2 <sup>nd</sup> Examiner	Weighted Kappa	0.9219	0.0495	0.8249	1.0000
3 <sup>rd</sup> Examiner	Weighted Kappa	0.7022	0.1187	0.4696	0.9349

**Table 3.3.2** Intra-examiner reproducibility for T2 WSL scores for the three examiners. The weighted Kappa values, the asymptotic standard errors valve (ASE) and the 95% Confidence limits are given.

Examiner	Fleiss' Kappa	Value	ASE	95% Confidence Limits	
1 <sup>st</sup> Examiner	Weighted Kappa	0.9275	0.0490	0.8316	1.0000
2 <sup>nd</sup> Examiner	Weighted Kappa	0.8347	0.0658	0.7057	0.9637
3 <sup>rd</sup> Examiner	Weighted Kappa	0.4758	0.1462	0.1892	0.7624

**Table 3.3.3** Inter-examiner reliability for T0, T1 and T2 WSL scores among the three examiners during the **first evaluation session**. The Kendall's Coefficient of Concordance (Coeff of Concordance), test statistic of the F-test (F), the numerator degrees of freedom (Num DF), the denominator degrees of freedom (Denom DF) and the corresponding p-Value (Prob>F) are given.

WSL -Score	Coeff of Concordance	F	Num DF	Denom DF	Prob>F
T0	0.75320	6.10367	38.3333	76.6667	<.0001
T1	0.83119	9.84763	38.3333	76.6667	<.0001
T2	0.80087	8.04379	38.3333	76.6667	<.0001

**Table 3.3.4** Inter-examiner reliability for T0, T1 and T2 WSL scores among the three examiners during the **second evaluation session**. The Kendall's Coefficient of Concordance (Coeff of Concordance), test statistic of the F-test (F), the numerator degrees of freedom (Num DF), the denominator degrees of freedom (Denom DF) and the corresponding p-Value (Prob>F) are given.

WSL -Score	Coeff of Concordance	F	Num DF	Denom DF	Prob>F
T0	0.78448	7.27985	38.3333	76.6667	<.0001
T1	0.82004	9.11340	38.3333	76.6667	<.0001
T2	0.82004	9.11340	38.3333	76.6667	<.0001

## Statistical analysis

All data from the case documentary sheets were entered into Microsoft Office 2007 Excel and controlled twice to optimize the data entry accuracy. The collected data were statistically evaluated in cooperation with the Institute for Medical Information of the Justus-Liebig-University of Giessen using SAS version 9.

Besides normal descriptive statistics the following statistical tests were used: Fisher's Exact Test was used to assess possible gender (Table 4.1.1, Table 4.4.1) and age (Table 4.1.2, Table 4.4.2) groups differences of WSL prevalence at T0 and T1. The Cochran-Mantel-Haenszel Statistics were applied to test whether any one of the four UFT exhibits a higher tendency to develop WSL at T0 or T1 (Table 4.2.1, Table 4.5.1). Furthermore, the Sign Test was used to assess possible gender (Table 4.7.1) and teeth differences for T2 changes (Table 4.8.1). The different tests are used because of the change of scoring index used between T0, T1 and T2.

## 4 RESULTS

### 4.1 Before treatment (T0) – Patients

Before treatment 271 patients (67.7%) did not exhibit any WSL on the labial surface of the four UFT. 108 patients (39.9%) of the WSL free patients were males and 163 patients (60.1%) were females. On the other hand, 129 patients (32.3%) showed WSL of different severity on the labial surface of the four UFT. 60 patients (46.5%) of the patients that exhibited WSL were males and 69 patients (53.5%) were females (Table 4.1.1, Figure 4.1.1).

It was found that the prevalence of WSL before treatment did not differ between the gender groups as 70.3% of the females and 64.3% of the males were WSL free at T0. No severity differences were seen neither between the genders ( $p= 0.286$ ) nor the age groups ( $p= 0.8923$ ) (Table 4.1.1, Table 4.1.2, Figure 4.1.1, Figure 4.1.4).

The majority of the 129 patients (86.8%) presenting WSL at T0 had mild lesions while the remaining WSL patients were affected severely either without (9.3%) or with cavitations (3.9%) on the labial surface of the four UFT (Figure 4.1.3).

**Table 4.1.1** Distribution of the MB-patients according to WSL-Index scores at T0 and gender. The numbers of patients (n), the percentages of patients from the total 400 patients (Total Pct), and the percentages of patients per column (Col Pct) are given.

Gender WSL-Score	Male	Female
No WSL	n = 108 27% Total Pct 64.3% Col Pct	n = 163 40.7% Total Pct 70.3% Col Pct
Slight WSL	n = 50 12.5% Total Pct 29.7% Col Pct	n = 62 15.5% Total Pct 26.7% Col Pct
Severe WSL	n = 8 2% Total Pct 4.8% Col Pct	n = 4 1% Total Pct 1.7% Col Pct
Cavitation	n = 2 0.5% Total Pct 1.2% Col Pct	n = 3 0.8% Total Pct 1.3% Col Pct
Total	n = 168 42% Total Pct	n = 232 58% Total Pct

#### Fisher's Exact Test

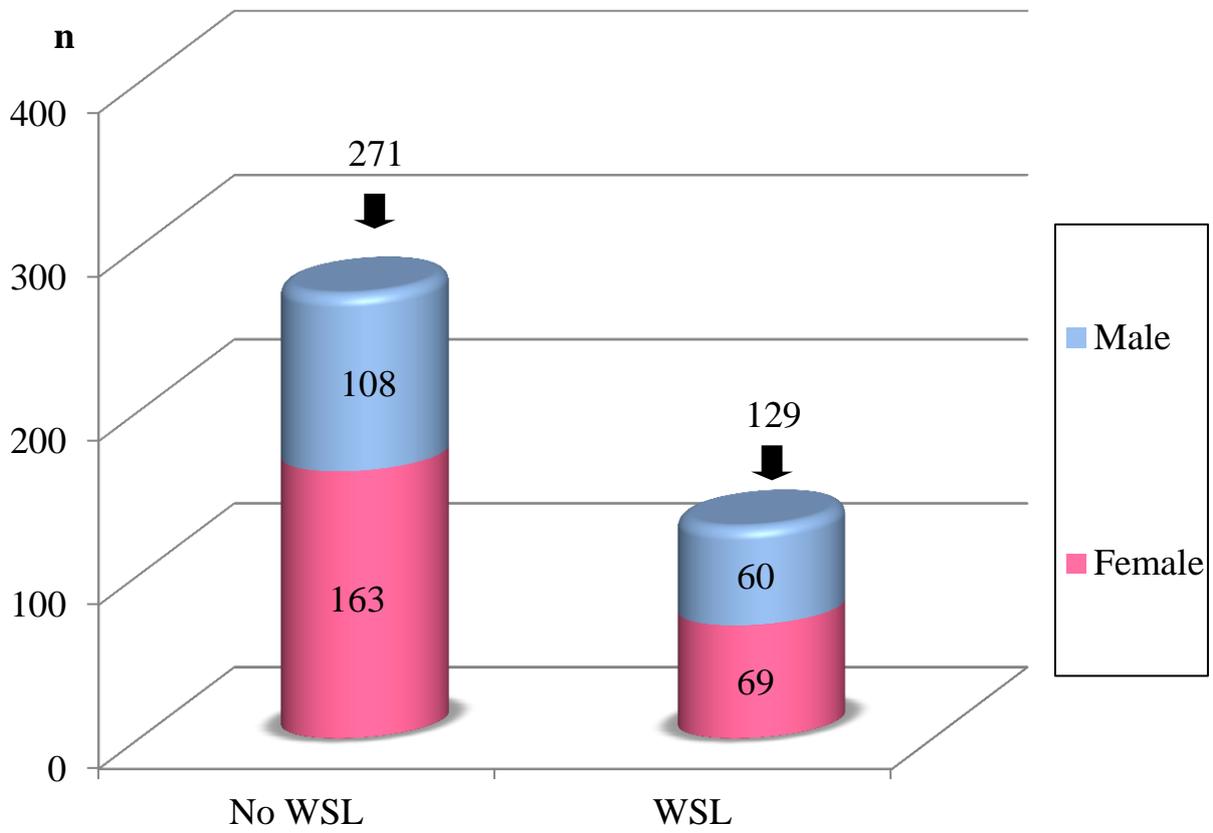
Table Probability (p)	<b>0.0011</b>
Pr <= P	0.2856

**Table 4.1.2** Distribution of the 400 MB-patients according to WSL-Index scores at T0 and the three age groups at T0. The number of patients (n), the percentages of patients from the total 400 patients (Total Pct), the percentage of patients per row (Row Pct) and the percentages of patients per column (Col Pct) are given.

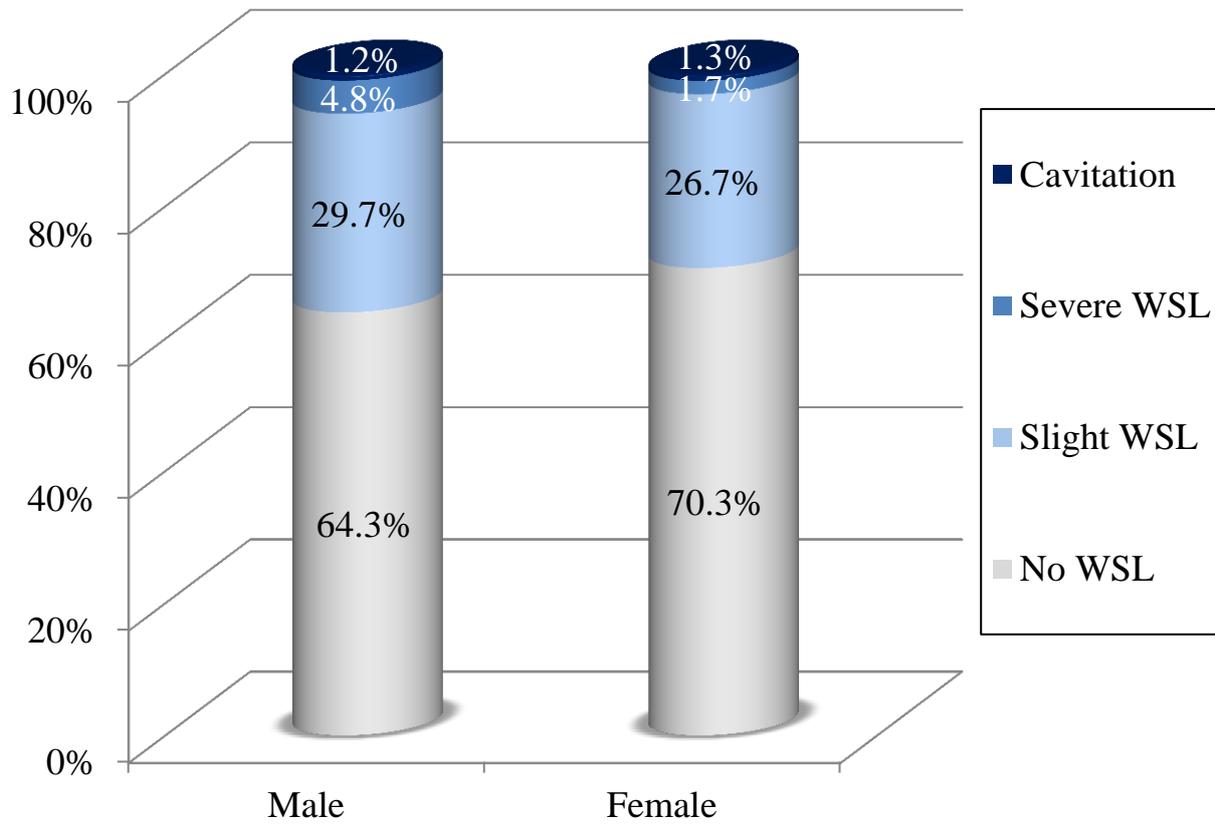
Age Group WSL-Score	Age < 12 yrs.	12-16 yrs.	Age > 16 yrs.	Total
No WSL	n = 75 18.8% Total Pct 27.7% Row Pct 68.2% Col Pct	n = 164 41% Total Pct 60.5% Row Pct 66.9% Col Pct	n = 32 8% Total Pct 11.8% Row Pct 71.1% Col Pct	n = 271 67.7% Total Pct
Slight WSL	n = 31 7.8% Total Pct 27.6% Row Pct 28.2% Col Pct	n = 71 17.8% Total Pct 63.4% Row Pct 29% Col Pct	n = 10 2.5% Total Pct 9% Row Pct 22.2% Col Pct	n = 112 28% Total Pct
Severe WSL	n = 3 0.7% Total Pct 25% Row Pct 2.7% Col Pct	n = 7 1.8% Total Pct 58.3% Row Pct 2.9% Col Pct	n = 2 0.5% Total Pct 16.7 Row Pct 4.4% Col Pct	n = 12 3% Total Pct
Cavitation	n = 1 0.3% Total Pct 20% Row Pct 0.9% Col Pct	n = 3 0.8% Total Pct 60% Row Pct 1.2% Col Pct	n = 1 0.3% Total Pct 20% Row Pct 2.2% Col Pct	n = 5 1.3% Total Pct
Total	n = 110 27.6% Total Pct	n = 245 61.2% Total Pct	n = 45 11.2% Total Pct	n = 400 100% Total Pct

**Fisher's Exact Test**

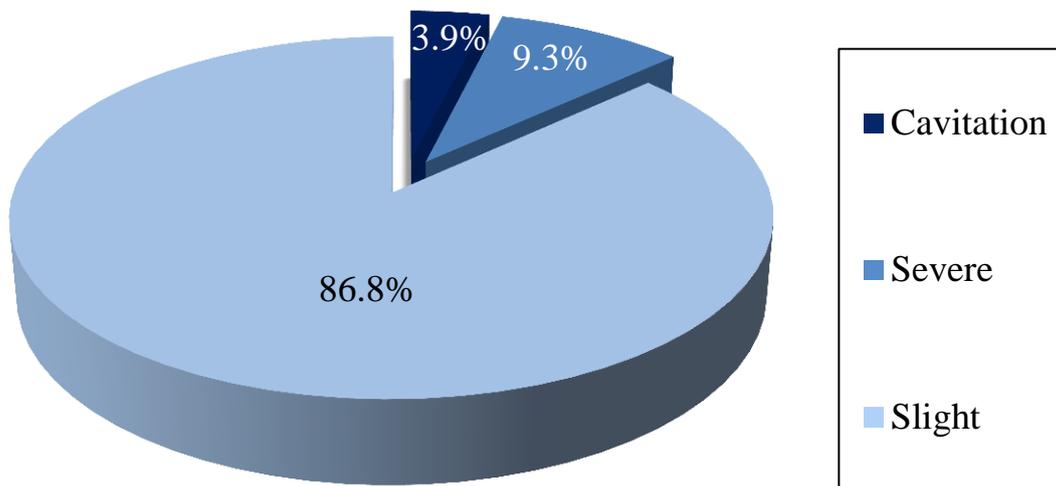
<b>Table Probability (P)</b>	<b>1.060E-04</b>
Pr <= P	0.8923



**Figure 4.1.1** Distribution of the 400 MB-patients (n) according to presence or absence of WSL at T0 and gender.

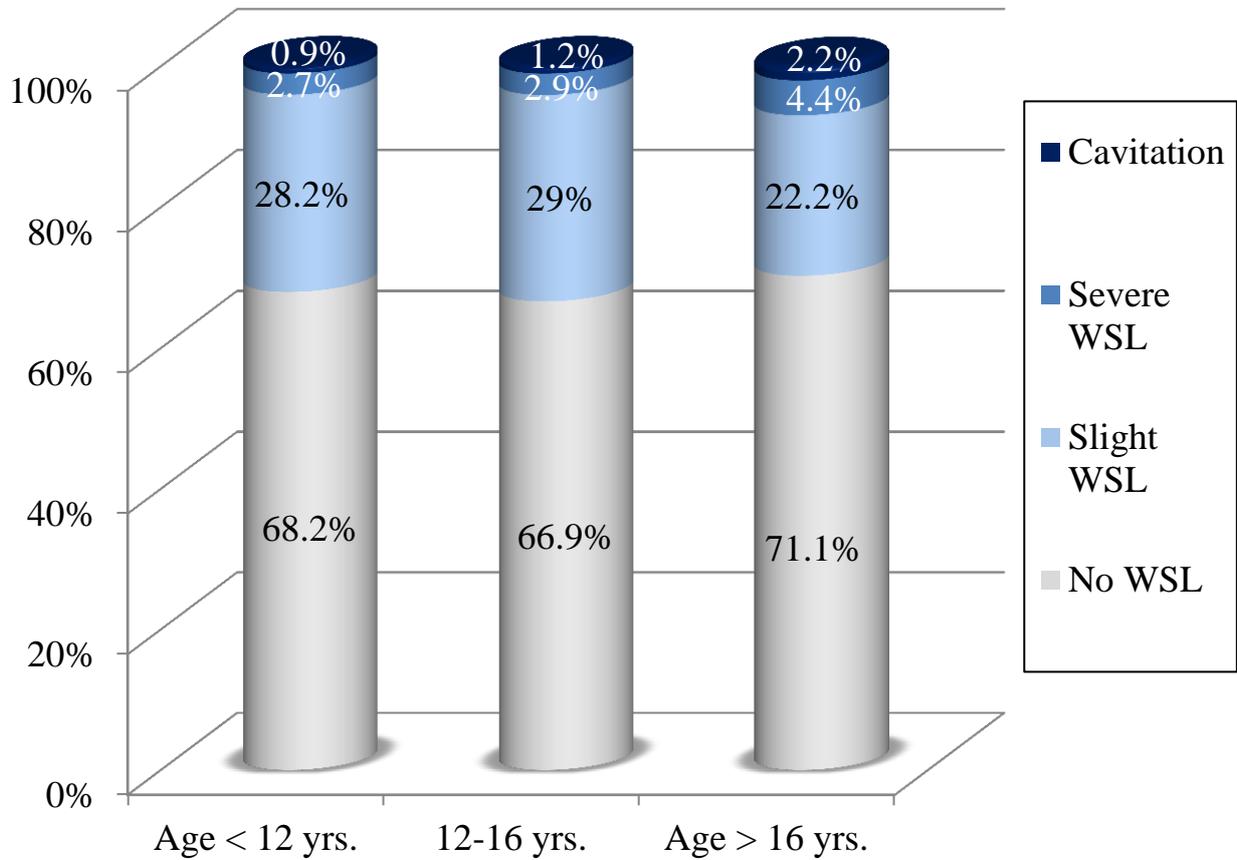


**Figure 4.1.2** Frequency (%) of the WSL-Index scores at T0 among the gender groups. The percentages of patients from the total number of their gender (Col Pct in Table 4.1.1) are given.



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**Figure 4.1.3** Frequency (%) of the severity of WSL among the 129 patient exhibiting WSL at T0.



**Figure 4.1.4** Frequency of the WSL-Index scores at T0 among the three age groups at T0. The percentages of patients from the total number of their related age category (Col Pct. in Table 4.1.2) are given.

#### 4.2 Before treatment (T0) – Teeth

Among the 1600 UFT that were evaluated 1285 teeth (80.3%) were WSL free before treatment, while 315 teeth (19.7%) exhibited WSL with different degrees of severity. The majority of the UFT (n= 277 / 87.9%) had mild lesions, while the remaining UFT were affected severely either without (n= 33 /10.5%) or with cavitations (n= 5 / 1.6%) as shown in Table 4.2.1 and Figure 4.2.1.

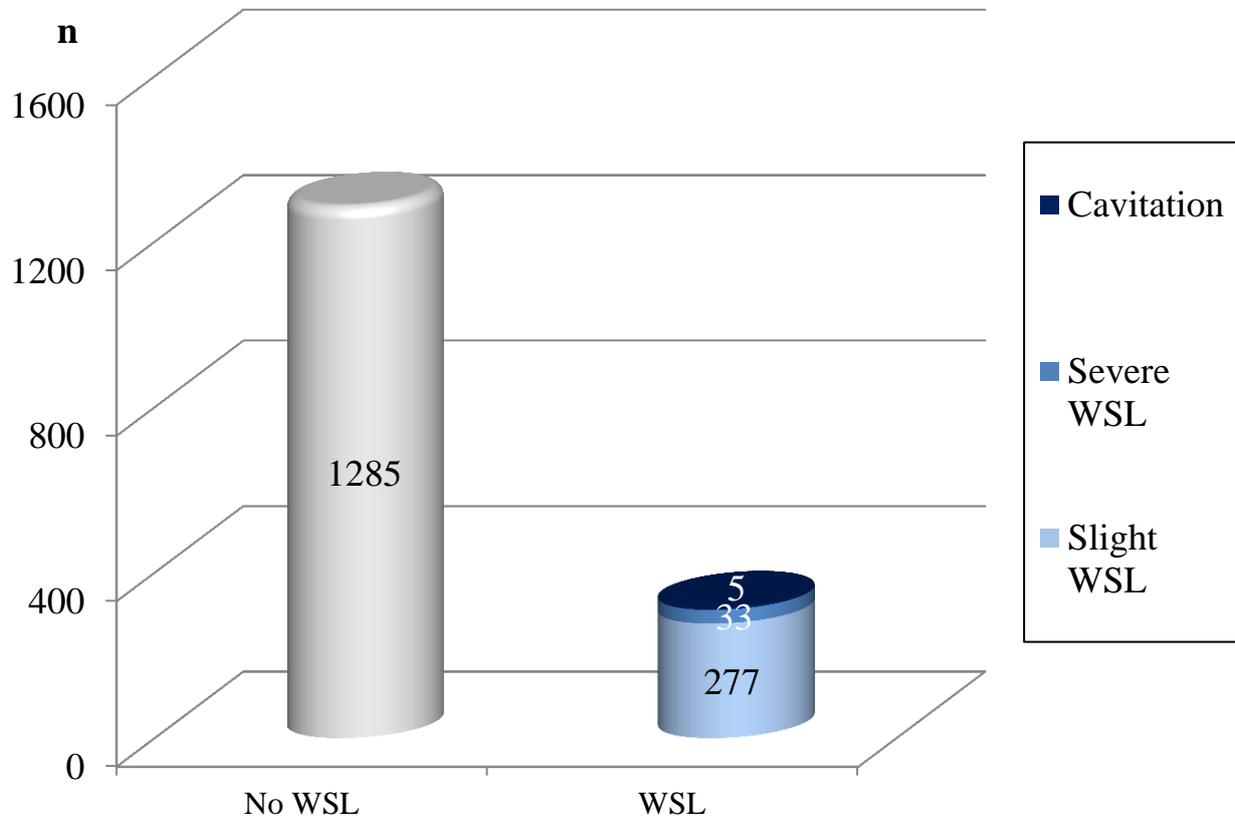
The distribution of the teeth according to WSL-Index scores at T0 showed no relevant tendency of any of the four UFT to exhibit more WSL ( $p= 0.1541$ ) (Table 4.2.1, Figure 4.2.2).

**Table 4.2.1** Distribution of the 1600 teeth according to WSL-Index scores at T0. The numbers (n) and the percentage (%) of teeth are given.

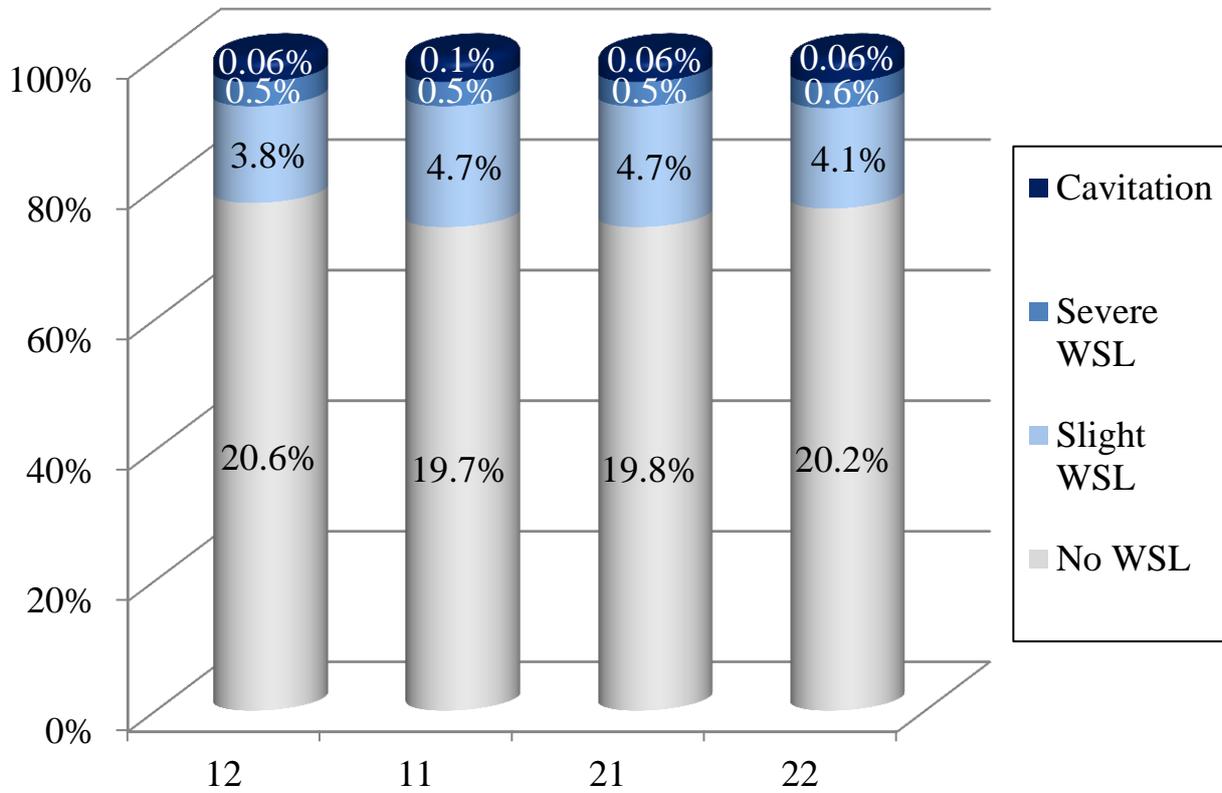
Teeth WSL-Score	12	11	21	22	sum
No WSL	n = 330 20.6%	n = 315 19.7%	n = 316 19.8%	n = 324 20.2%	n = 1285 80.3%
Slight WSL	n = 61 3.8%	n = 75 4.7%	n = 75 4.7%	n = 66 4.1%	n = 277 17.3%
Severe WSL	n = 8 0.5%	n = 8 0.5%	n = 8 0.5%	n = 9 0.6%	n = 33 2.1%
Cavitation WSL	n = 1 0.06%	n = 2 0.1%	n = 1 0.06%	n = 1 0.06%	n = 5 0.3 %

**Cochran-Mantel-Haenszel Statistics (Based on Rank Scores)**

Statistic	Alternative Hypothesis	DF	Value	Prob
1	Nonzero Correlation	1	0.2801	0.5966
2	Row Mean Scores Differ	3	5.2541	0.1541



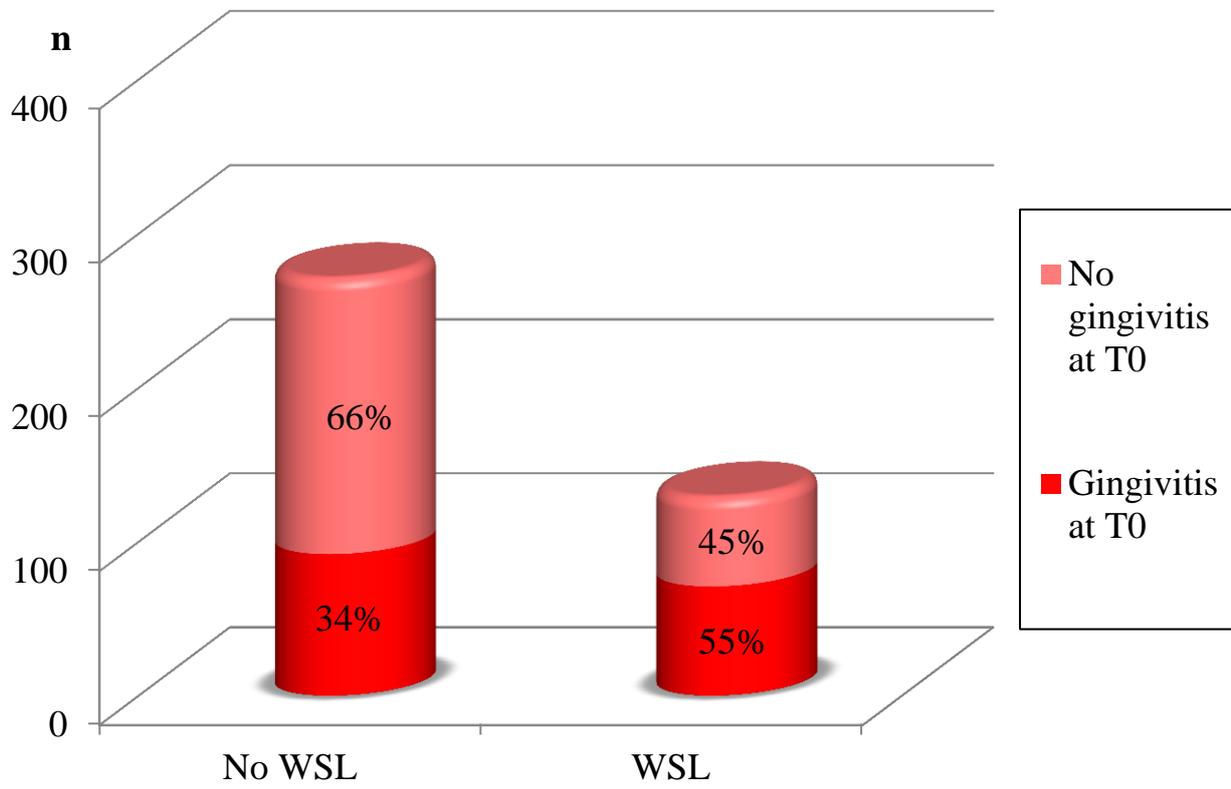
**Figure 4.2.1** Distribution of the 1600 teeth(n) according to WSL-Index Scores at T0.



**Figure 4.2.2** Frequency (%) of the WSL-Index scores at T0 among the four UFT.

### 4.3 Association between WSL at T0 and Gingivitis at T0

Of the 271 patients that were WSL free before treatment, 66% had not shown gingivitis whereas 34% of the patients exhibited gingivitis at T0. On the other hand, from the 129 patients that exhibited WSL before treatment, 55% showed while 45% did not show gingivitis before treatment (Figure 4.3.1).



**Figure 4.3.1** Distribution of the 400 MB-patients (n) according to presence or absence of WSL at T0 and gingivitis at T0.

#### 4.4 After treatment (T1) – Patients

After treatment 106 (26.5%) of the 400 patients did not exhibit WSL on the labial surface of any of the four UFT. 42 (39.6%) of the WSL free patients were males and 64 (60.3%) were females. On the other hand, 294 (73.5%) of the 400 MB-patients exhibited WSL with different severities on the labial surfaces of at least one of the four UFT. 126 patients (42.9%) that exhibited WSL were males and 168 patients (57.1%) were females. The prevalence of WSL after treatment showed a gender influence in the distribution of WSL ( $p=0.0182$ ) with male WSL-patients tending to exhibit more severe WSL than females (Table 4.4.1, Figure 4.4.2).

Almost two thirds (63.3%) of the WSL patients had mild lesions while the remaining WSL patients were affected severely either without (26.9%) or with cavitations (9.9%) on the labial surface of the four UFT at T1 (Figure 4.4.3).

According to the patient's distribution by WSL-Index scores and the T0 age groups, patients aged 12-16 years old showed a slight tendency ( $p= 0.0663$ ) to develop more WSL than the younger and older groups (Table 4.4.2, Figure 4.4.4).

The active treatment time of the WSL free patients at T1 was on average 1.9 years (SD 0.8) and the longest treatment lasted for 4.5 years. The active treatment time of the patients with WSL at T1 was exactly the same (1.9 yrs. / 0.8 SD) except for the maximum treatment length that lasted for 7.5 years.

From the 271 WSL-free patients at T0, 39.1% remained WSL free at T1 whereas 45.8% showed slight WSL, while the remaining patients were affected severely either without (13.3%) or with cavitation (1.8%) as shown in Figure 4.4.5. Thus, the sample incidence rate for WSL (T1-T0) amounted to 60.9 % of the patients.

More than the half (54.5%) of the 112 patients that exhibited slight WSL at T0 remained unchanged at T1, while the remaining patients were affected severely either without (34.8%) or with cavitation (10.7%) as shown in Figure 4.4.6.

From the 12 patients that exhibited severe WSL at T0, 8.3% showed improvement from severe to slight WSL at T1. One third (33.3%) of the patients remained unchanged, while the remaining majority (58.3%) of the patients developed cavitations at T1 as shown in Figure 4.4.7. The 5 patients that affected severely with cavitation at T0 remained exhibiting cavitation at T1 (Figure 4.4.8).

**Table 4.4.1** Distribution of the MB-patients according WSL-Index scores at T1 and gender. The numbers of patients (n), the percentages of patients from the total 400 patients (Total Pct), and the percentages of patients per column (Col Pct) are given.

Gender WSL-Score	Male	Female
No WSL	n = 42 10.5% Total Pct 25% Col Pct	n = 64 16% Total Pct 27.6% Col Pct
Slight WSL	n = 67 16.8% Total Pct 39.9 % Col Pct	n = 119 29.7% Total Pct 51.3% Col Pct
Severe WSL	n = 43 10.7% Total Pct 25.6% Col Pct	n = 36 9% Total Pct 15.5% Col Pct
Cavitation	n = 16 4% Total Pct 9.5% Col Pct	n = 13 3.2% Total Pct 5.6% Col Pct
Total	n = 168 42% Total Pct	n = 232 58% Total Pct

### Fisher's Exact Test

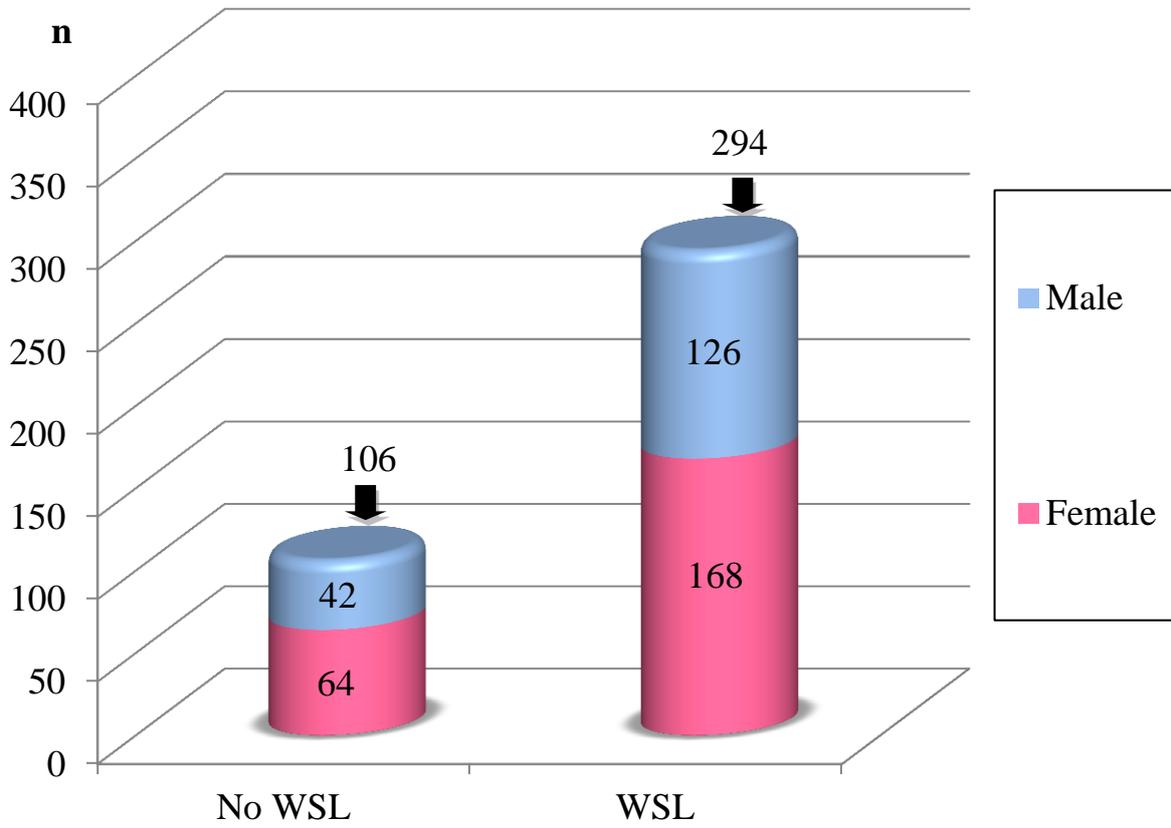
<b>Table Probability (P)</b>	<b>1.075E-05</b>
Pr <= P	0.0182

**Table 4.4.2** Distribution of the 400 MB-patients according to WSL-Index scores at T1 and the three age groups at T0. The number of patients (n), the percentages of patients from the total 400 patients (Total Pct), the percentage of patients per row (Row Pct) and the percentages of patients per column (Col Pct) are given.

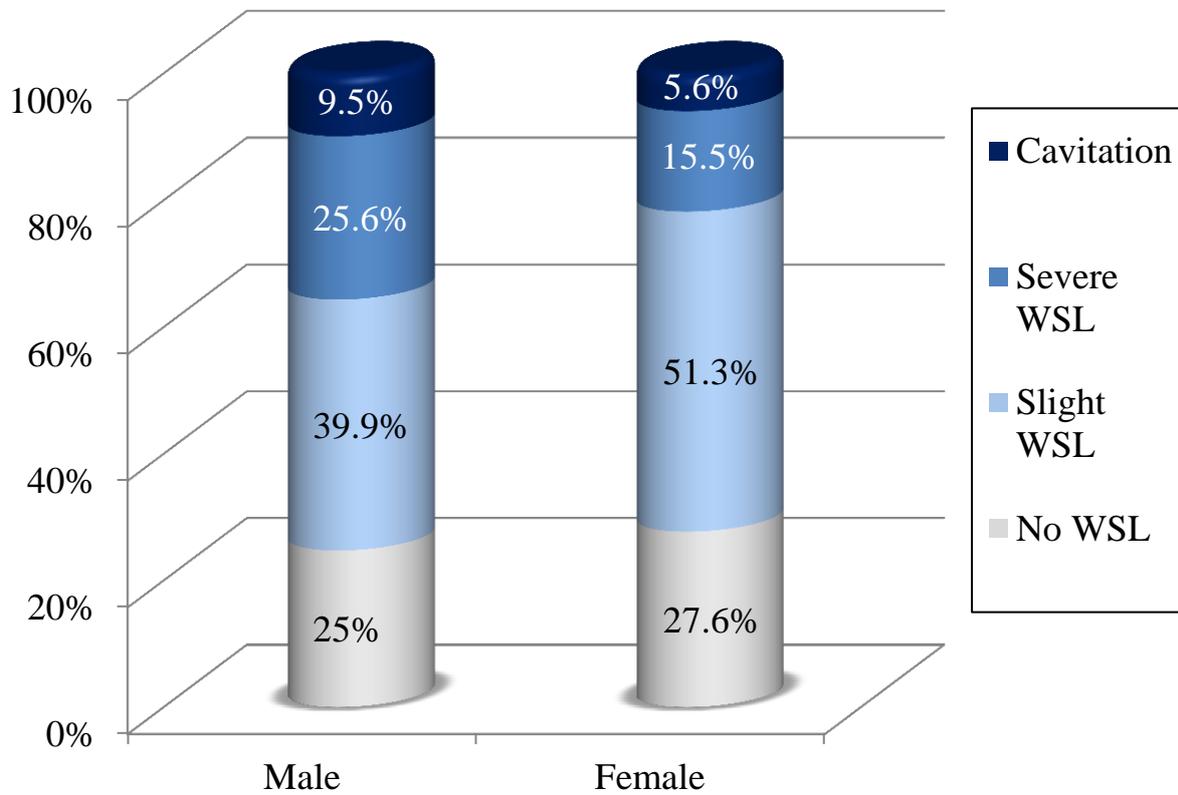
Age Group WSL -Score	Age < 12 yrs.	12-16 yrs.	Age > 16 yrs.	Total
No WSL	n = 33 8.3% Total Pct 31.1% Row Pct 30% Col Pct	n = 55 13.7% Total Pct 51.9% Row Pct 22.4% Col Pct	n = 18 4.5% Total Pct 17% Row Pct 40% Col Pct	n = 106 26.5% Total Pct
Slight WSL	n = 45 11.2% Total Pct 24.2% Row Pct 41% Col Pct	n = 121 30.3% Total Pct 65.1% Row Pct 49.4% Col Pct	n = 20 5% Total Pct 10.7% Row Pct 44.4% Col Pct	n = 186 46.5% Total Pct
Severe WSL	n = 24 6% Total Pct 30.4% Row Pct 21.8% Col Pct	n = 52 13% Total Pct 65.8% Row Pct 21.2% Col Pct	n = 3 0.8% Total Pct 3.8% Row Pct 6.7% Col Pct	n = 79 19.8% Total Pct
Cavitation	n = 8 2% Total Pct 27.6% Row Pct 7.3% Col Pct	n = 17 1.2% Total Pct 58.6% Row Pct 7% Col Pct	n = 4 1% Total Pct 13.8% Row Pct 8.9% Col Pct	n = 29 7.2 % Total Pct
Total	n = 110 27.6% Total Pct	n = 245 61.2% Total Pct	n = 45 11.2% Total Pct	n = 400 100% Total Pct

#### Fisher's Exact Text

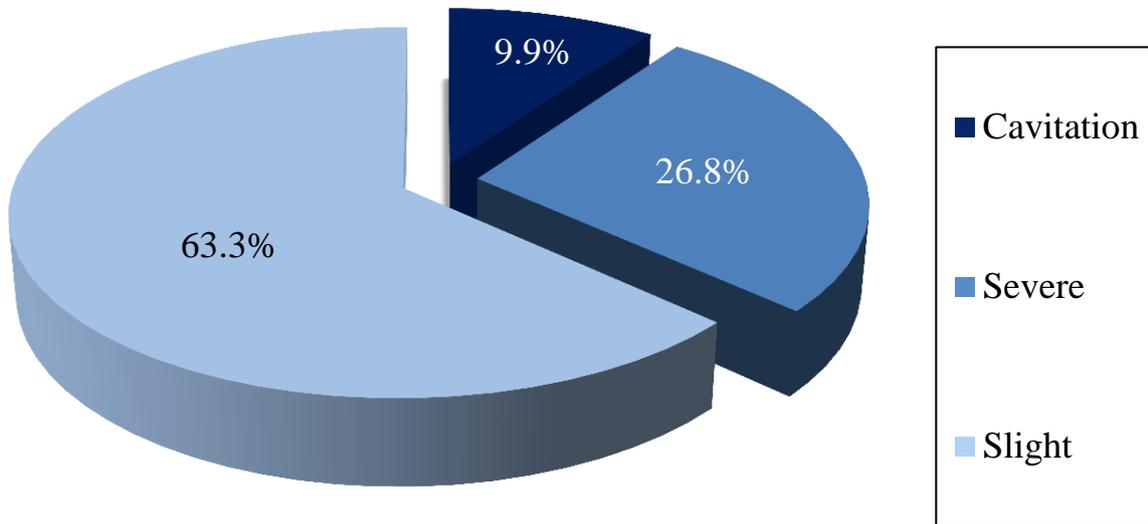
Table Probability (P)	4.137E-08
Pr <= P	0.0663



**Figure 4.4.1** Distribution of the 400 MB patients at T1 (n) according to presence or absence of WSL and gender.

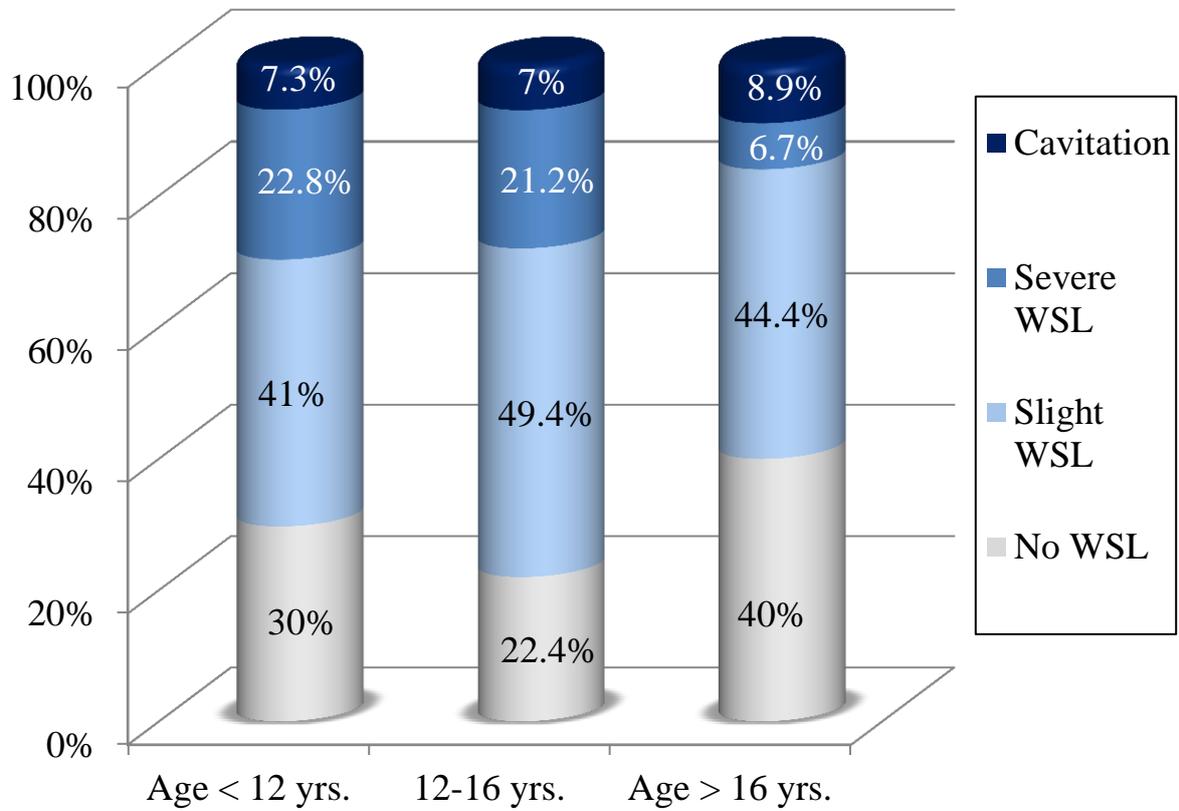


**Figure 4.4.2** Frequency (%) of the WSL-Index scores at T1 among the gender groups. The percentages of patients from the total number of their gender (Col Pct in Table 4.4.1) are given.

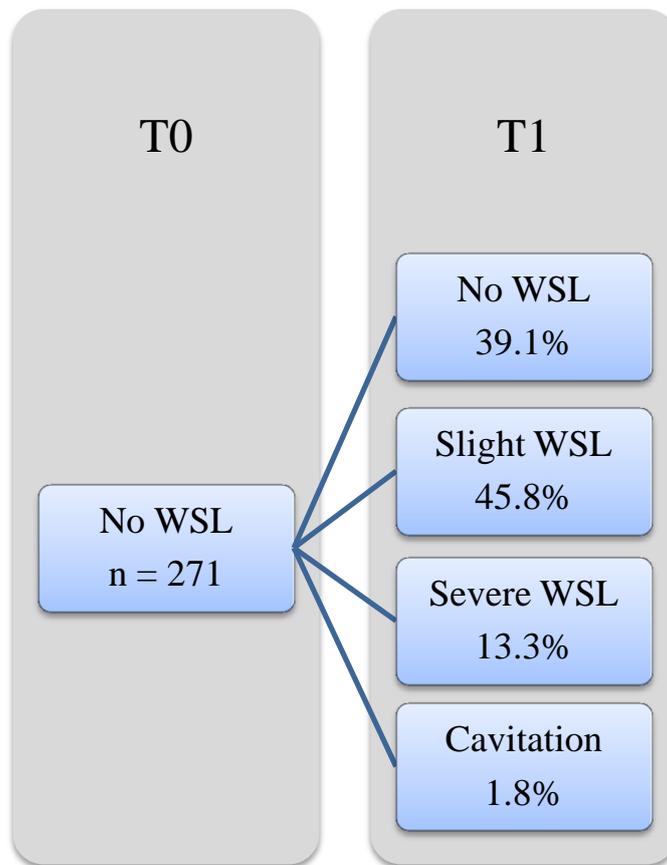


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**Figure 4.4.3** Frequency (%) of the severity of WSL among the 294 patient exhibiting WSL at T1.

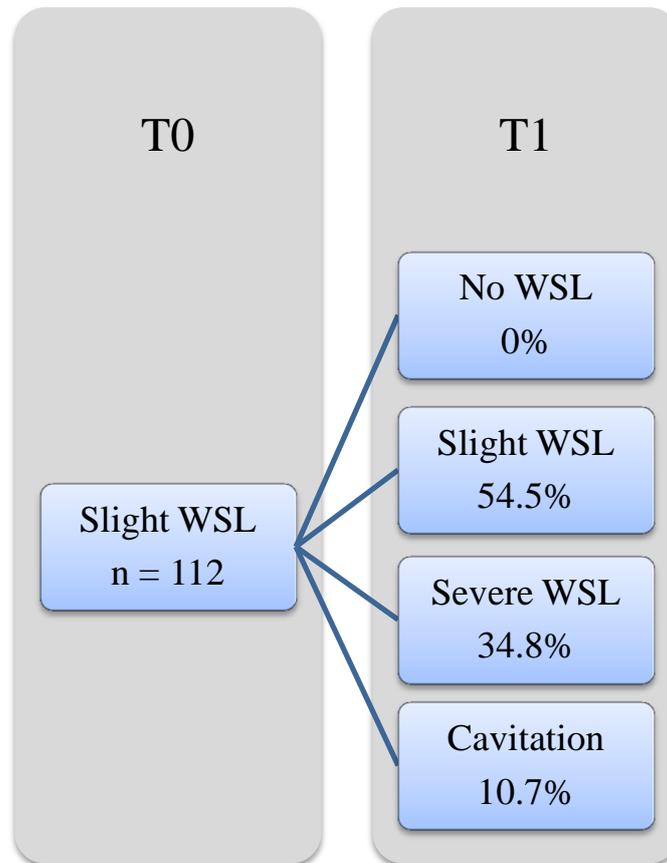


**Figure 4.4.4** Frequency of the WSL-Index scores at T1 among the three age groups at T0. The percentages of patients from the total number of their related age category (Col Pct in Table 4.4.2) are given.

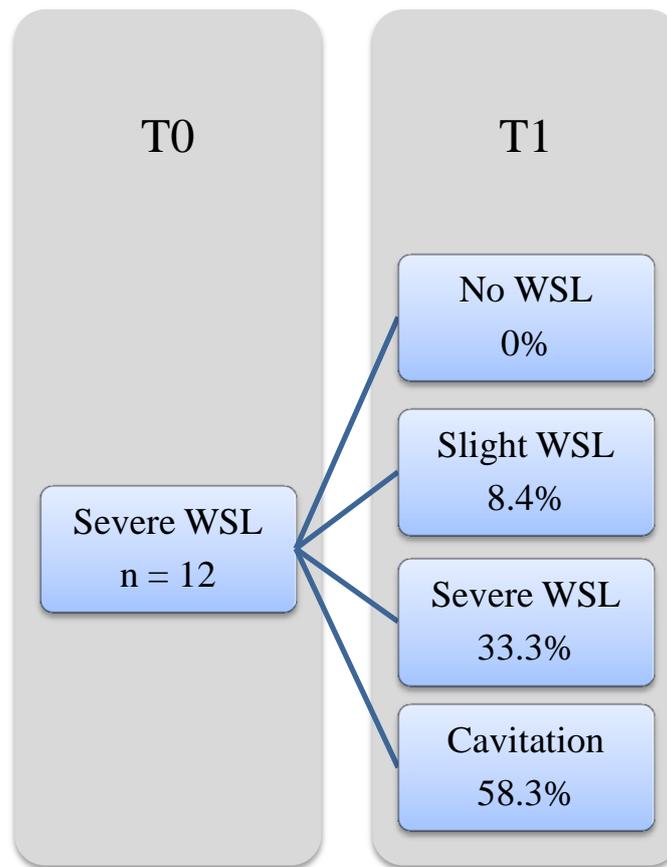


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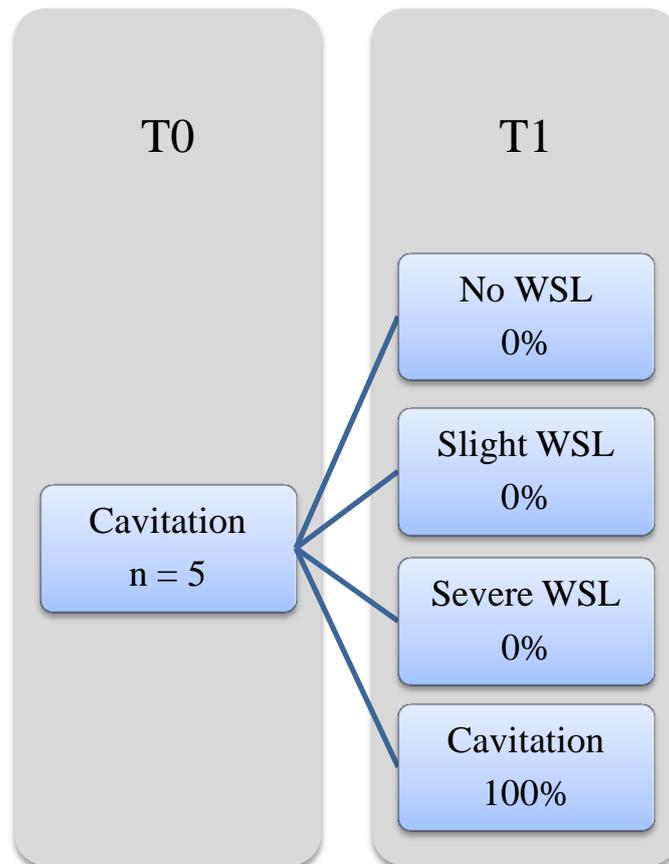
**Figure 4.4.5** Flow chart representing the changes in the 271 patients (n) with no WSL at T0. Their percentage (%) distribution among the four WSL-Index groups after treatment (T1) is given.



**Figure 4.4.6** Flow chart representing the changes in the 112 patients (n) with slight WSL at T0. Their percentage (%) distribution among the four WSL-Index groups after treatment (T1) is given.



**Figure 4.4.7** Flow chart representing the changes in the 12 patients (n) with severe WSL at T0. Their percentage (%) distribution among the four WSL-Index groups after treatment (T1) is given.



**Figure 4.4.8** Flow chart representing the changes in the 5 patients (n) with cavitation at T0. Their percentage (%) distribution among the four WSL-Index groups after treatment (T1) is given.

#### 4.5 After treatment (T1) – Teeth

Among the 1600 UFT that were evaluated 681 teeth (42.6%) were WSL free after treatment, while 919 teeth (57.4%) exhibit WSL of different degrees of severity. About 41.2% of the UFT had mild lesions while the remaining UFT were affected severely either without (12.4%) or with cavitations (3.8%) on the labial surface of the four UFT (Figure 4.5.1).

Distribution of the teeth according to WSL-Index scores at T1 showed no relevant tendency of any of the four UFT to exhibit more WSL, however the upper lateral incisors showed a tendency ( $p= 0.0209$ ) to exhibit more severe WSL either with or without cavitation (Table 4.5.1, Figure 4.5.2).

The distribution of the 400 UFT (12-22) according to WSL-index scores at T0 and T1 is shown in the tables 4.5.2 to 4.5.5. About 50-60% of the teeth without WSL or slight WSL at T0 remained constant with respect to their WSL severity score, while around 1/3 deteriorated one degree. Teeth with severe WSL at T0 and here especially the lateral incisors exhibited a notable tendency ( $\sim 2/3$ ) to deteriorate, thus exhibiting cavitation after treatment.

**Table 4.5.1** Distribution of the 1600 teeth according to WSL-Index scores at T1. The numbers (n) and the percentage (%) of teeth are given.

Teeth WSL-Score	12	11	21	22	sum
No WSL	n = 171 10.7%	n = 179 11.2%	n = 178 11.1%	n = 153 9.6%	n = 681 42.6%
Slight WSL	n = 149 9.3%	n = 171 10.7%	n = 172 10.8%	n = 167 10.4%	n = 659 41.2%
Severe WSL	n = 58 3.6%	n = 40 2.5%	n = 40 2.5%	n = 61 3.8%	n = 199 12.4%
Cavitation WSL	n = 22 1.4%	n = 10 0.6%	n = 10 0.6%	n = 19 1.2%	n = 61 3.8%

**Cochran-Mantel-Haenszel Statistics (Based on Rank Scores)**

Statistic	Alternative Hypothesis	DF	Value	Prob
1	Nonzero Correlation	1	0.8759	0.3493
2	Row Mean Scores Differ	3	9.7416	0.0209

**Table 4.5.2** Distribution of the 400 **right upper lateral incisors (12)** according to WSL-index scores at T1 and T0. The number of patients (n), the percentages of patients from the total 400 teeth (Total Pct), the percentages of patients per row (Row Pct) and the percentages of patients per column (Col Pct) are given.

WSL-Score (T1) \ WSL-Score (T0)	No WSL	Slight WSL	Severe WSL	Cavitation	Total
No WSL	n = 171 42.8% Total Pct 51.8% Row Pct 100% Col Pct	n = 111 27.8% Total Pct 33.6% Row Pct 74.5% Col Pct	n = 39 9.8% Total Pct 11.8% Row Pct 67.2% Col Pct	n = 9 2.3% Total Pct 2.7% Row Pct 40.9% Col Pct	n = 330 82.5% Total Pct
Slight WSL	n = 0 0% Total Pct 0% Row Pct 0% Col Pct	n = 37 9.3% Total Pct 60.7% Row Pct 24.8% Col Pct	n = 18 4.5% Total Pct 29.5% Row Pct 31% Col Pct	n = 6 1.5% Total Pct 9.8% Row Pct 27.3% Col Pct	n = 61 15.3% Total Pct
Severe WSL	n = 0 0% Total Pct 0% Row Pct 0% Col Pct	n = 1 0.3% Total Pct 12.5% Row Pct 0.7% Col Pct	n = 1 0.3% Total Pct 12.5% Row Pct 1.7% Col Pct	n = 6 1.5% Total Pct 75% Row Pct 27.3% Col Pct	n = 8 2% Total Pct
Cavitation	n = 0 0% Total Pct 0% Row Pct 0% Col Pct	n = 0 0% Total Pct 0% Row Pct 0% Col Pct	n = 0 0% Total Pct 0% Row Pct 0% Col Pct	n = 1 0.3% Total Pct 100% Row Pct 4.5% Col Pct	n = 1 0.3% Total Pct
Total	n = 171 42.8% Total Pct	n = 149 37.3% Total Pct	n = 58 14.5% Total Pct	n = 22 5.5% Total Pct	n = 400 100% Total Pct

**Table 4.5.3** Distribution of the 400 **right upper central incisors (11)** according to WSL-Index scores at T1 and T0. The number of patients (n), the percentages of patients from the total 400 teeth (Total Pct), the percentages of patients per row (Row Pct) and the percentages of patients per column (Col Pct) are given.

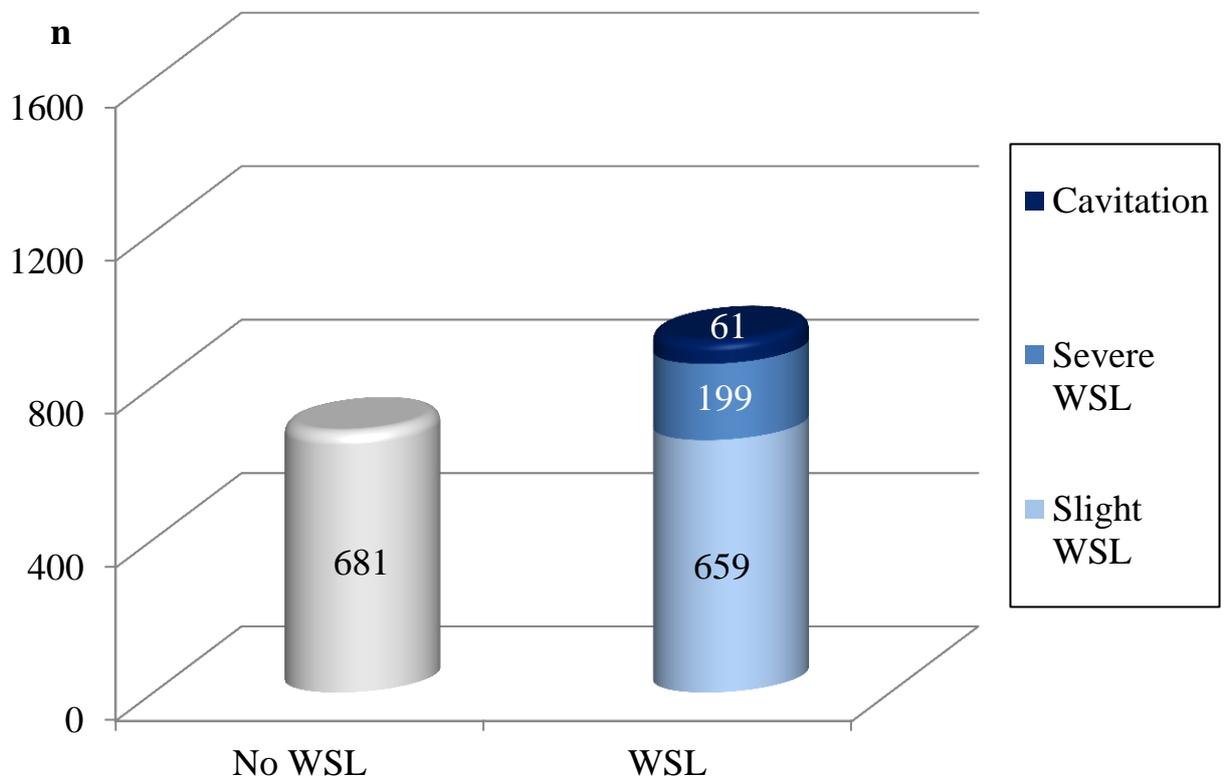
WSL-Score (T1) \ WSL-Score (T0)	No WSL	Slight WSL	Severe WSL	Cavitation	Total
No WSL	n = 179 44.8% Total Pct 56.8% Row Pct 100% Col Pct	n = 116 29% Total Pct 36.8% Row Pct 67.8% Col Pct	n = 18 4.5% Total Pct 5.7% Row Pct 45% Col Pct	n = 2 0.5% Total Pct 0.6% Row Pct 20% Col Pct	n = 315 78.8% Total Pct
Slight WSL	n = 0 0% Total Pct 0% Row Pct 0% Col Pct	n = 53 13.3% Total Pct 60.7% Row Pct 31% Col Pct	n = 18 4.5% Total Pct 24% Row Pct 45% Col Pct	n = 4 1% Total Pct 5.3% Row Pct 40% Col Pct	n = 75 18.8% Total Pct
Severe WSL	n = 0 0% Total Pct 0% Row Pct 0% Col Pct	n = 2 0.5% Total Pct 25% Row Pct 1.2% Col Pct	n = 4 1% Total Pct 50% Row Pct 10% Col Pct	n = 2 0.5% Total Pct 25% Row Pct 20% Col Pct	n = 8 2% Total Pct
Cavitation	n = 0 0% Total Pct 0% Row Pct 0% Col Pct	n = 0 0% Total Pct 0% Row Pct 0% Col Pct	n = 0 0% Total Pct 0% Row Pct 0% Col Pct	n = 2 0.5% Total Pct 100% Row Pct 20% Col Pct	n = 2 0.5% Total Pct
Total	n = 179 44.8% Total Pct	n = 171 42.8% Total Pct	n = 40 10% Total Pct	n = 10 2.5% Total Pct	n = 400 100% Total Pct

**Table 4.5.4** Distribution of the 400 **left upper central incisors (21)** according to WSL-Index scores at T1 and T0. The number of patients (n), the percentages of patients from the total 400 teeth (Total Pct), the percentages of patients per row (Row Pct) and the percentages of patients per column (Col Pct) are given.

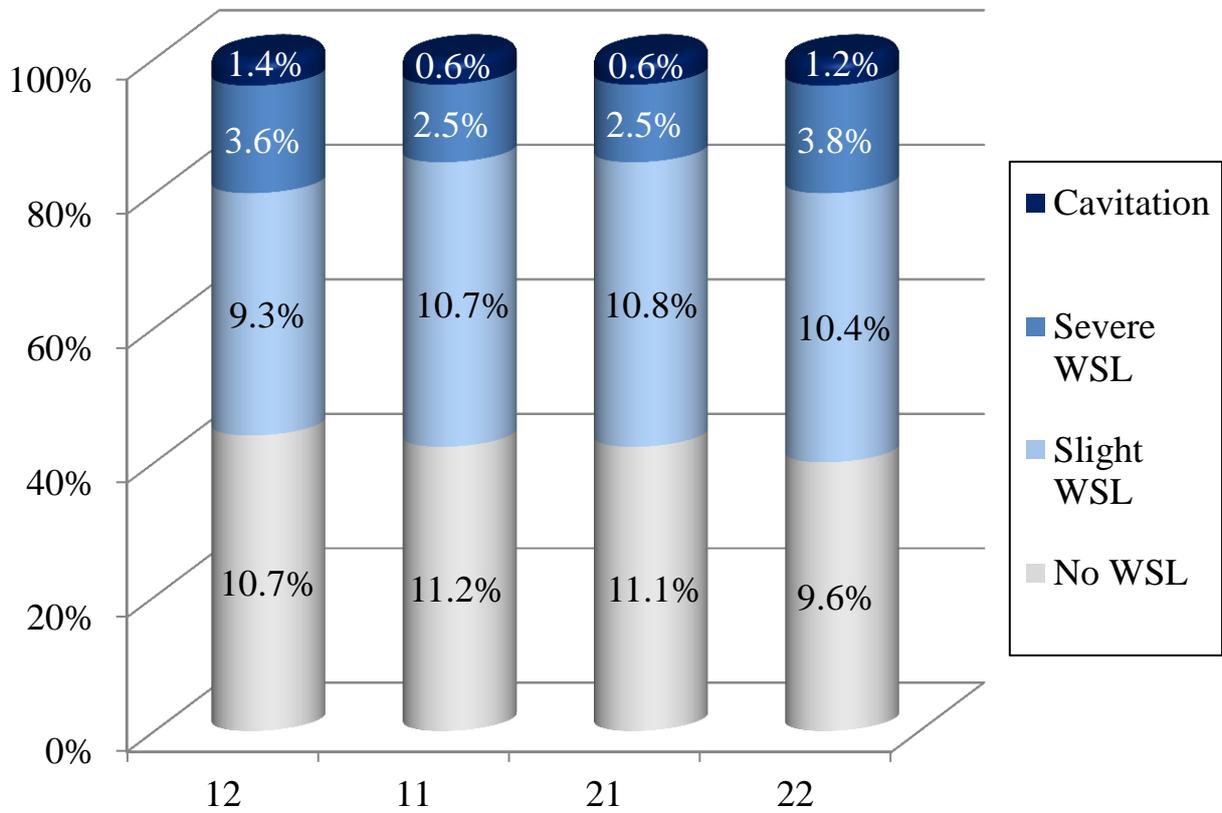
WSL-Score (T1) \ WSL-Score (T0)	No WSL	Slight WSL	Severe WSL	Cavitation	Total
No WSL	n = 178 44.5% Total Pct 56.3% Row Pct 100% Col Pct	n = 122 30.5% Total Pct 38.6% Row Pct 70.9% Col Pct	n = 15 3.8% Total Pct 4.7% Row Pct 37.5% Col Pct	n = 1 0.3% Total Pct 0.3% Row Pct 10% Col Pct	n = 316 79% Total Pct
Slight WSL	n = 0 0% Total Pct 0% Row Pct 0% Col Pct	n = 48 12% Total Pct 64% Row Pct 27.9% Col Pct	n = 22 5.5% Total Pct 29.3% Row Pct 55% Col Pct	n = 5 1.3% Total Pct 6.7% Row Pct 50% Col Pct	n = 75 18.8% Total Pct
Severe WSL	n = 0 0% Total Pct 0% Row Pct 0% Col Pct	n = 2 0.5% Total Pct 25% Row Pct 1.2% Col Pct	n = 3 0.8% Total Pct 37.5% Row Pct 7.5% Col Pct	n = 3 0.8% Total Pct 37.5% Row Pct 30% Col Pct	n = 8 2% Total Pct
Cavitation	n = 0 0% Total Pct 0% Row Pct 0% Col Pct	n = 0 0% Total Pct 0% Row Pct 0% Col Pct	n = 0 0% Total Pct 0% Row Pct 0% Col Pct	n = 1 0.3% Total Pct 100% Row Pct 10% Col Pct	n = 1 0.3% Total Pct
Total	n = 178 44.5% Total Pct	n = 172 43% Total Pct	n = 40 10% Total Pct	n = 10 2.5% Total Pct	n = 400 100% Total Pct

**Table 4.5.5** Distribution of the 400 **left upper lateral incisors (22)** according to WSL-Index scores at T1 and T0. The number of patients (n), the percentages of patients from the total 400 teeth (Total Pct), the percentages of patients per row (Row Pct) and the percentages of patients per column (Col Pct) are given.

WSL-Score (T1) \ WSL-Scores (T0)	No WSL	Slight WSL	Severe WSL	Cavitation	Total
No WSL	n = 153 38.3% Total Pct 47.2% Row Pct 100% Col Pct	n = 126 31.5% Total Pct 38.9% Row Pct 75.4% Col Pct	n = 38 9.5% Total Pct 11.7% Row Pct 62.3% Col Pct	n = 7 1.8% Total Pct 2.2% Row Pct 36.8% Col Pct	n = 324 81% Total Pct
Slight WSL	n = 0 0% Total Pct 0% Row Pct 0% Col Pct	n = 41 10.3% Total Pct 62.1% Row Pct 24.6% Col Pct	n = 20 5% Total Pct 30.3% Row Pct 32.8% Col Pct	n = 5 1.3% Total Pct 7.6% Row Pct 26.3% Col Pct	n = 66 16.5% Total Pct
Severe WSL	n = 0 0% Total Pct 0% Row Pct 0% Col Pct	n = 0 0% Total Pct 0% Row Pct 0% Col Pct	n = 3 0.8% Total Pct 33.3% Row Pct 4.9% Col Pct	n = 6 1.5% Total Pct 66.7% Row Pct 31.6% Col Pct	n = 9 2.3% Total Pct
Cavitation	n = 0 0% Total Pct 0% Row Pct 0% Col Pct	n = 0 0% Total Pct 0% Row Pct 0% Col Pct	n = 0 0% Total Pct 0% Row Pct 0% Col Pct	n = 1 0.3% Total Pct 100% Row Pct 5.3% Col Pct	n = 1 0.3% Total Pct
Total	n = 153 38.2% Total Pct	n = 167 41.8% Total Pct	n = 61 15.3% Total Pct	n = 19 4.8% Total Pct	n = 400 100% Total Pct



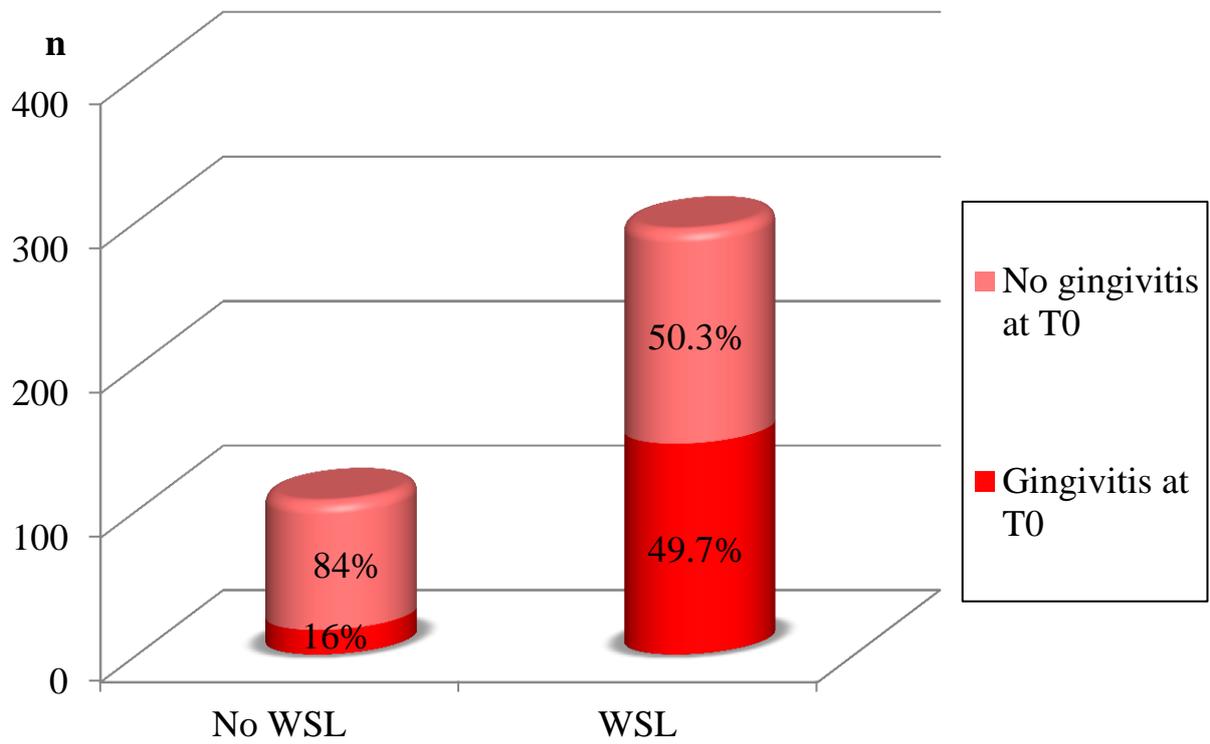
**Figure 4.5.1** Distribution of the 1600 teeth (n) according to WSL-Index Scores at T1.



**Figure 4.5.2** Frequency (%) of the WSL-Index scores at T1 among the four UFT.

#### 4.6 Association between WSL at T1 and Gingivitis at T0

Between the 106 WSL-free patients after treatment, 16% had shown while 84% had not shown gingivitis before treatment. On the other hand, from the 294 patients that exhibited WSL after treatment, 49.7% had shown while 50.3% had not shown gingivitis before treatment (Figure 4.6.1). Thus, there seemed to be a tendency of WSL-free patients at T1 to show lower gingivitis prevalence at T0. No such tendencies were seen for patients that did develop WSL during treatment.



**Figure 4.6.1** Distribution of the 400 MB-patients (n) according to presence or absence of WSL at T1 and gingivitis at T0.

#### 4.7 After retention (T2) – Patients

From the start of treatment until the end of retention 104 (26%) MB-patients remained entirely WSL free. Following the further course of the 294 patients that exhibited WSL with different severities on the labial surfaces of the four UFT at T1 revealed that the majority 57.1% of the WSL patients showed improvement. About 26% of the WSL patients remained unchanged and 16.7% of the WSL patients deteriorated (Table 4.7.1 and Figure 4.7.1)

WSL-free patients at T1 had a great tendency (98%) to remain WSL-free at T2, while two patients developed new WSL during the retention period (Figure 4.7.2). The great majority (62.9%) of the slight WSL-patients at T1 showed improvement at T2, while 27.4% were unchanged and 9.7% worsened (Figure 4.7.3). About half (50.6%) of the severe WSL-patients at T1 showed improved WSL at T2, while 30.4% were unchanged and 19% worsened (Figure 4.7.4). On the other hand, 55% of the patients that exhibited cavitation at T1 showed deterioration at T2, while about 37.9% showed improvement and just 7% were unchanged (Figure 4.7.5).

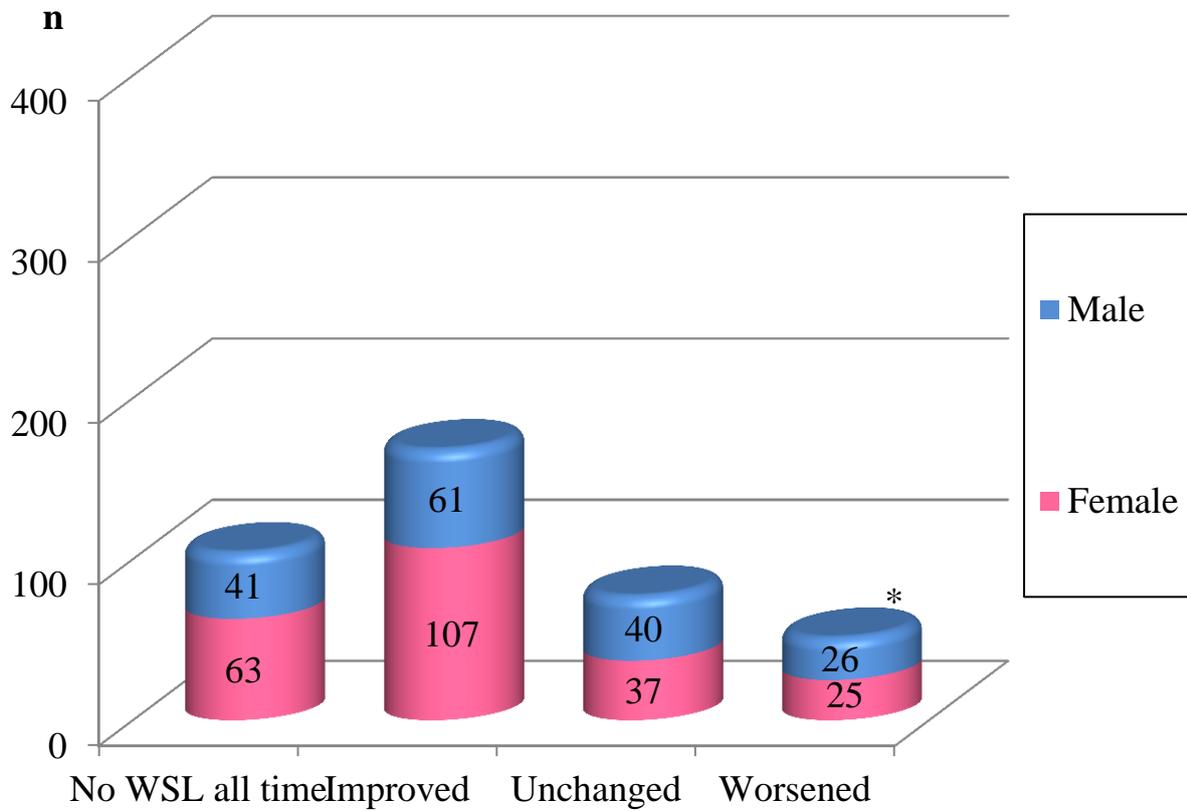
Slight WSL-patients showed a considerable potential to improve with time as 69.6% of the improved WSL-patients had slight WSL at T1, while 23.9% had severe WSL and just 6.5% cavitation (Figure 4.7.6). Patients with slight WSL also showed a great potential to remain stable as about two third of the unchanged WSL patients had slight WSL at T1, while 31.2% had severe WSL and 2.6% cavitation (Figure 4.7.7). There was no remarkable potential of any of the WSL-Index groups at T1 to dominate the worsened WSL-patients group at T2 as they were almost equally distributed with exception for the WSL free patients at T1 (3.9%) as seen in Figure 4.3.8.

With respect to gender distribution among the WSL-Change groups it was noticed that females tended to show slightly more improved WSL (46.1% vs. 36.3% Col Pct) compared to males that presented more unchanged WSL (23.8% vs. 15.9% Col Pct) or worsened (15.5% vs. 10.8% Col Pct) (Table 4.7.1, Figure 4.7.1).

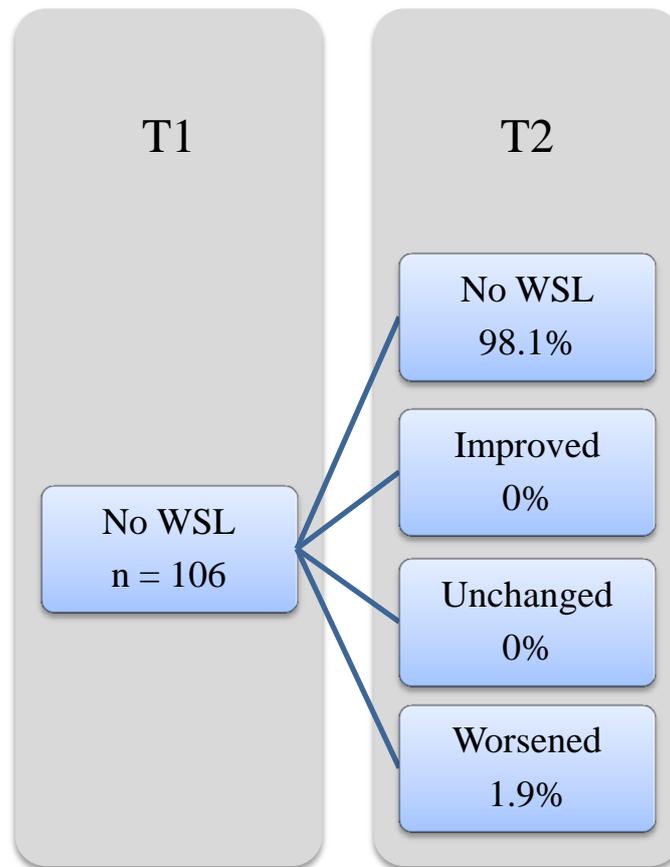
The retention time was on average 2 years (SD 0.72) for all patients, whereas the longest retention time was 6.1 years. There were no differences with respect to the active treatment or retention times between WSL free patients and the other WSL-Change groups.

**Table 4.7.1** Distribution of the MB-patients according to WSL-Change groups at T2 and gender. The numbers of patients (n), the percentages of patients from the total 400 patients (Total Pct), the percentages of patients per row (Row Pct) and the percentages of patients per column (Col Pct) are given.

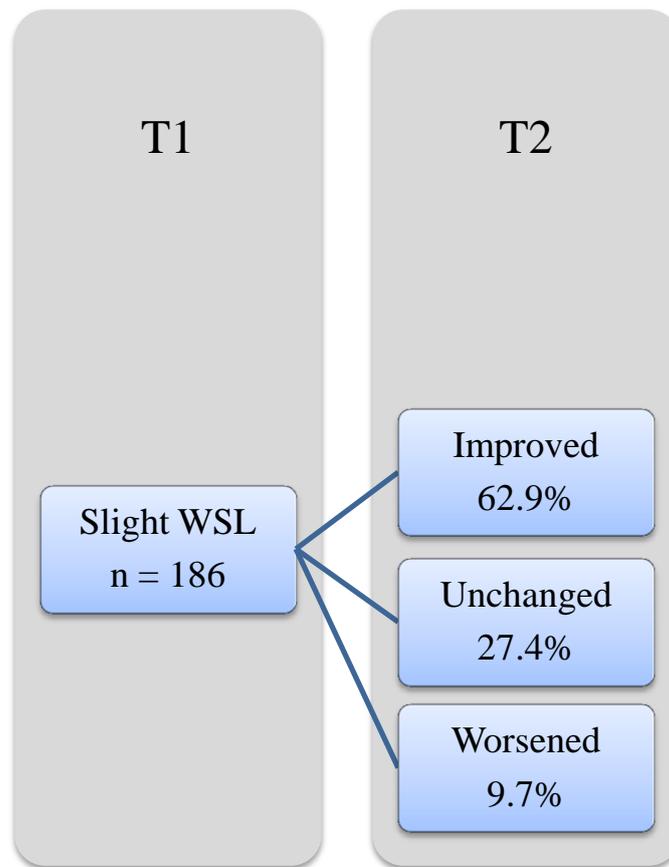
Gender WSL score	Male	Female	Total
No WSL all time	n = 41 10.3% Total Pct 39.4% Row Pct 24.4% Col Pct	n = 63 15.7% Total Pct 60.6% Row Pct 27.1% Col Pct	n = 104 26% Total Pct
Improved WSL	n = 61 15.2% Total Pct 36.3% Row Pct 36.3% Col Pct	n = 107 26.7% Total Pct 63.7% Row Pct 46.1% Col Pct	n = 168 42% Total Pct
Unchanged WSL	n = 40 10% Total Pct 51.9% Row Pct 23.8% Col Pct	n = 37 9.2% Total Pct 48% Row Pct 15.9% Col Pct	n = 77 19.2% Total Pct
Worsened WSL	n = 26 6.5% Total Pct 51% Row Pct 15.5% Col Pct	n = 25 6.2% Total Pct 49% Row Pct 10.8% Col Pct	n = 51 12.7% Total Pct
Total	n = 168 42% Total Pct	n = 232 58% Total Pct	n = 400 100% Total Pct



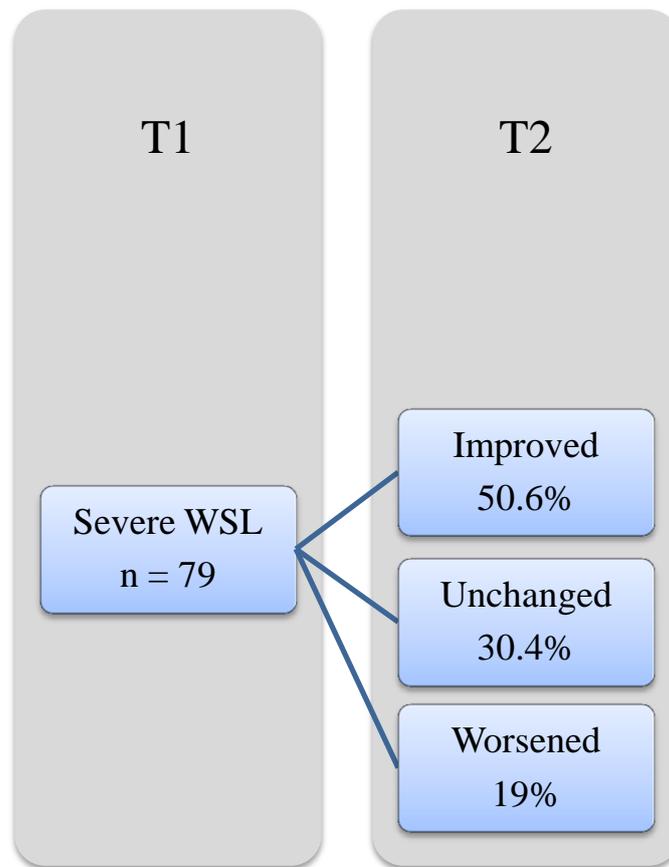
**Figure 4.7.1** Distribution of the 400 patients (n) according to WSLC groups at T2. The numbers of patients are given. \* Please note: 2 patients developed new WSL during the retention time.



**Figure 4.7.2** Flow chart representing the changes in the 106 patients (n) with no WSL at T1. Their percentage (%) distribution among the four WSL-Change groups after retention (T2) is given.

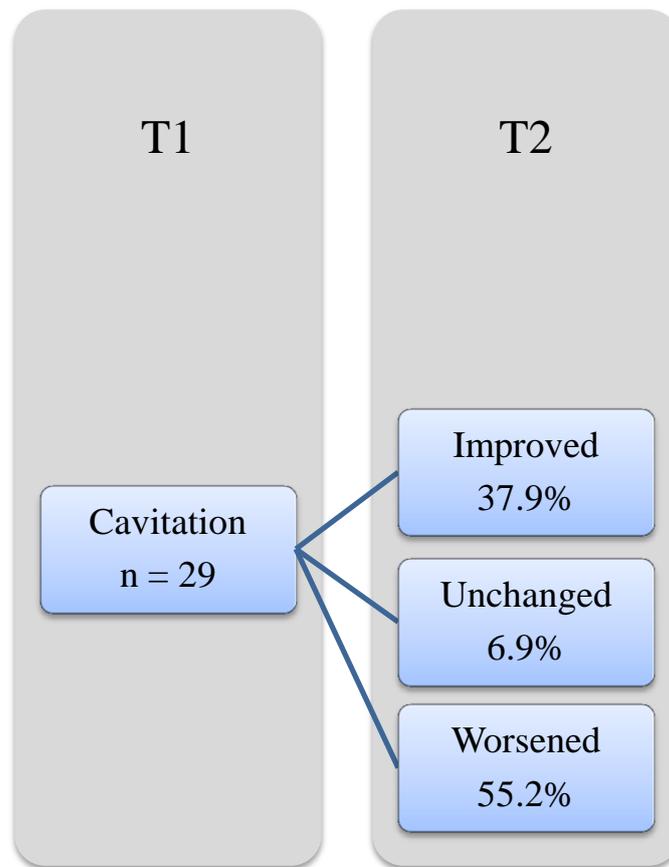


**Figure 4.7.3** Flow chart representing the changes in the 186 patients (n) with slight WSL at T1. Their percentage (%) distribution among the three WSL-Change groups after retention (T2) is given. No WSL group at T2 does not apply.



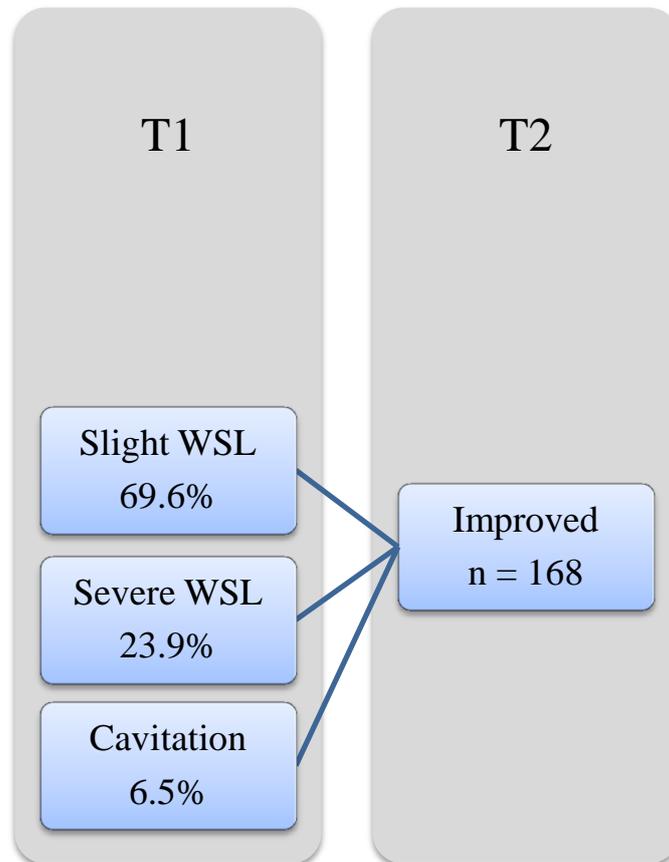
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**Figure 4.7.4** Flow chart representing the changes in the 79 patients (n) with severe WSL at T1. Their percentage (%) distribution among the three WSL-Change groups after retention (T2) is given. No WSL group at T2 does not apply.

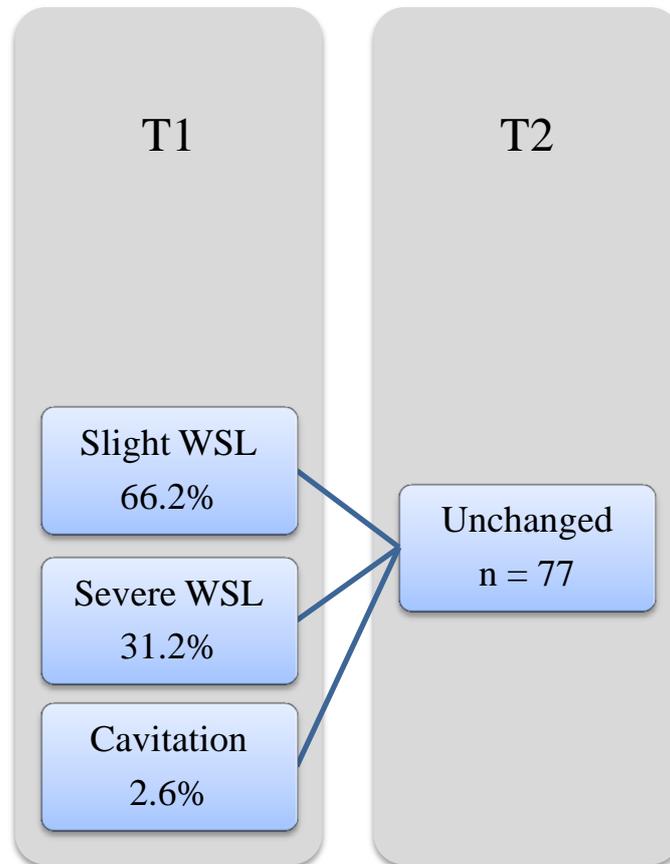


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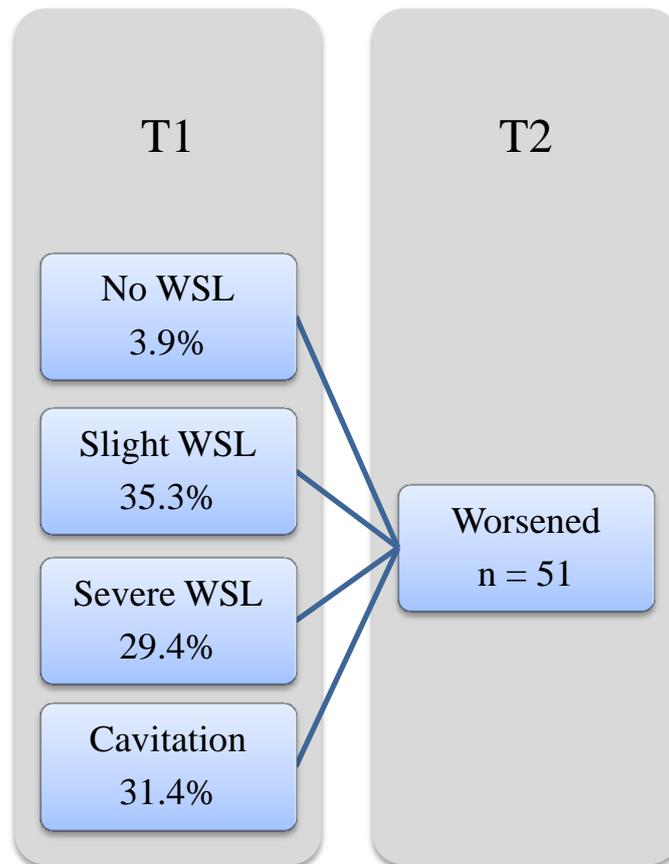
**Figure 4.7.5** Flow chart representing the changes in the 29 patients (n) with cavitation at T1. Their percentage (%) distribution among the three WSL-Change groups after retention (T2) is given. No WSL group at T2 does not apply.



**Figure 4.7.6** Flow chart representing the origin of the 168 patients (n) with improved WSL after retention (T2). Their percentage (%) distribution among the three WSL-Index groups at T1 is given. No WSL group at T2 does not apply.



**Figure 4.7.7** Flow chart representing the origin of the 77 patients (n) with unchanged WSL after retention (T2). Their percentage (%) distribution among the three WSL-Index groups at T1 is given. No WSL group at T2 does not apply.



**Figure 4.7.8** Flow chart representing the origin of the 51 patients (n) with worsened WSL after retention (T2). Their percentage (%) distribution among the four WSL-Index groups at T1 is given.

#### 4.8 After retention (T2) – Teeth

Among the 681 WSL-free teeth at T1, 673 (98.8%) teeth remained WSL free all the times until the end of the retention, while 8 teeth (1.2%) developed new WSL during the retention period (Table 4.8.1). From 919 WSL-teeth at T1 635 (69.1%) showed improvement at T2 and 192 (20.9%) remained exhibiting WSL with no alteration. On the other hand, 92 teeth (10%) exhibited deteriorated WSL (Figure 4.8.1). Thus, the probability to improve tended to be clearly higher ( $p < 0.001$ ), especially for the teeth with slight to severe WSL without cavitation (Tables 4.8.2 - 4.8.5).

Distribution of the teeth according to WSL-Change groups at T2 showed no relevant tendency of any of the four UFT to exhibit a higher percentage of WSL changes (Table 4.8.1, Figure 4.8.2). However, there was a clear tendency for females to exhibit more improved teeth than males ( $p < 0.001$ ).

**Table 4.8.1** Distribution of the 1600 teeth according to WSL-Change-Index scores at T2. The numbers (n) and the percentages (%) of teeth are given.

Teeth WSL-Score	12	11	21	22	sum
No WSL all time	n = 170 10.6%	n = 176 11%	n = 175 10.9%	n = 152 9.5%	n = 673 42%
Improved WSL	n = 149 9.3%	n = 147 9.2%	n = 161 10%	n = 178 11.1%	n = 635 39.7%
Unchanged WSL	n = 53 3.3-%	n = 52 3.2%	n = 40 2.5%	n = 47 2.9%	n = 192 12%
Worsened WSL	n = 28 1.3%	n = 25 1.6%	n = 24 1.5%	n = 23 1.4%	n = 100 6.3%

#### Sign-Test for WSL changed teeth T2

WSL	Count	p-value	
Improved WSL	635	$p \geq  M $	<.0001
Worsened WSL	100	$p \geq  S $	<.0001

#### Sign-Test for WSL changed teeth at T2 by gender

Gender	WSL	Count	p-value	
Male	Improved WSL	240	$p \geq  M $	<.0001
	Worsened WSL	53	$p \geq  S $	<.0001
Female	Improved WSL	394	$p \geq  M $	<.0001
	Worsened WSL	48	$p \geq  S $	<.0001

**Table 4.8.2** Distribution of the 400 **right upper lateral incisors (12)** according to WSL-Change-Index scores at T2 and WSL-Index scores at T1. The number of patients (n), the percentages of patients from the total 400 teeth (Total Pct), the percentage of patients per row (Row Pct) and the percentages of patients per column (Col Pct) are given. Fields that do not apply are blank, “No WSL all times” marked in grey and improvements are highlighted in green.

WSLC-Score (T2) \ WSL-Score (T1)	No WSL all times	Improved	Unchanged	Worsened	Total
No WSL	n = 170 42.7% Total Pct 99.4% Row Pct 100% Col Pct			n = 1 2.5% Total Pct 0.6% Row Pct 3.6% Col Pct	n = 171 42.7% Total Pct
Slight WSL		n = 100 25% Total Pct 67.1% Row Pct 67.1% Col Pct	n = 36 9% Total Pct 24.2% Row Pct 67.9% Col Pct	n = 13 3.3% Total Pct 8.7% Row Pct 46.4% Col Pct	n = 149 37.3% Total Pct
Severe WSL		n = 38 9.5% Total Pct 65.5% Row Pct 25.5% Col Pct	n = 15 3.7% Total Pct 25.9% Row Pct 28.3% Col Pct	n = 5 1.3% Total Pct 8.6% Row Pct 17.9% Col Pct	n = 58 14.5% Total Pct
Cavitation		n = 11 2.7% Total Pct 50% Row Pct 7.4% Col Pct	n = 2 0.5% Total Pct 9.1% Row Pct 3.8% Col Pct	n = 9 1.2% Total Pct 40.9% Row Pct 3.6% Col Pct	n = 22 5.5% Total Pct
<b>Total</b>	n = 170 42.7% Total Pct.	n = 149 37% Total Pct	n = 53 13.3% Total Pct	n = 28 7% Total Pct	n = 400 100% Total Pct

**Table 4.8.3** Distribution of the 400 **right upper central incisors (11)** according to WSL-Change-Index scores at T2 and WSL-Index scores at T1. The number of patients (n), the percentages of patients from the total 400 teeth (Total Pct), the percentage of patients per row (Row Pct) and the percentages of patients per column (Col Pct) are given. Fields that do not apply are blank, “No WSL all times” marked in grey and improvements are highlighted in green.

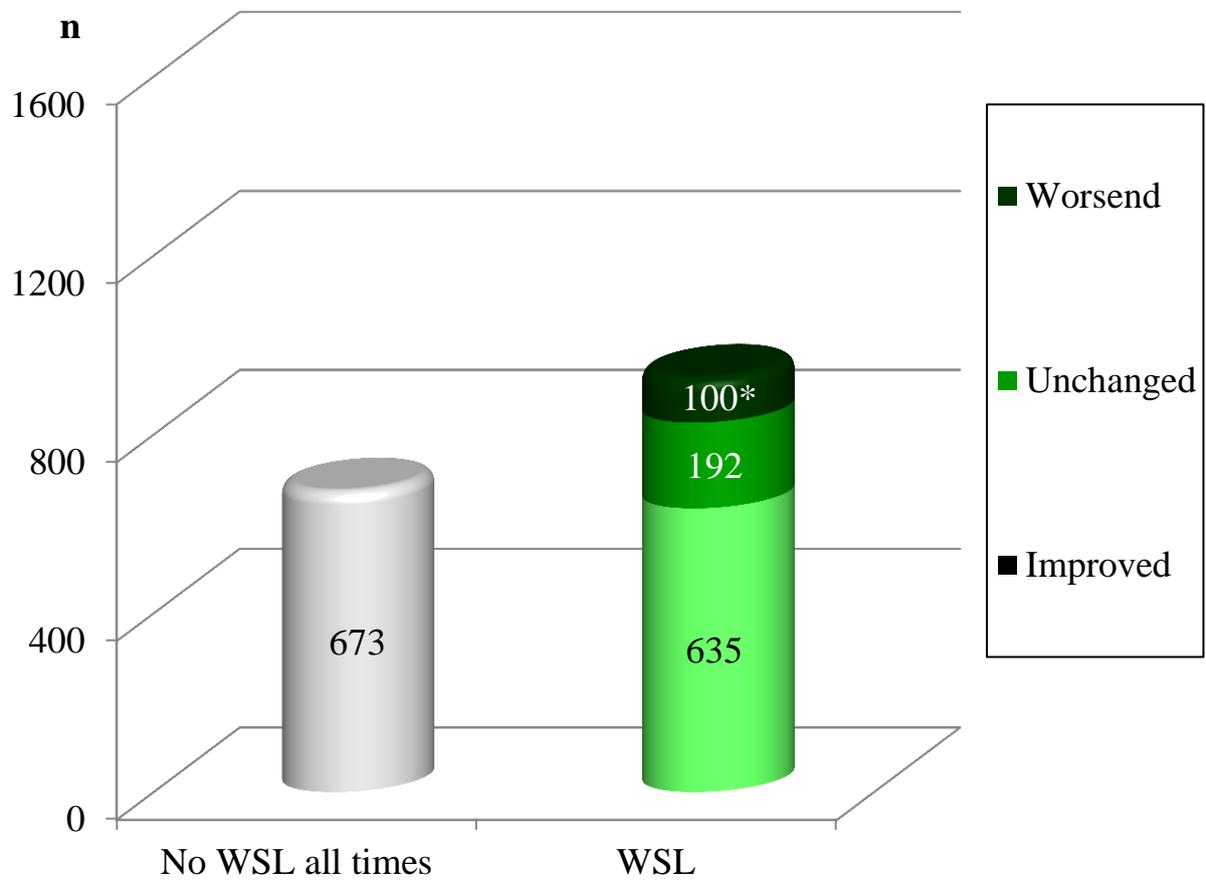
WSLC-Score (T2) \ WSL-Score (T1)	No WSL all times	Improved	Unchanged	Worsened	Total
No WSL	n = 176 44% Total Pct 98.3% Row Pct 100% Col Pct			n = 3 0.8% Total Pct 1.7% Row Pct 12% Col Pct	n = 179 44.8% Total Pct
Slight WSL		n = 111 27.8% Total Pct 64.9% Row Pct 78.7% Col Pct	n = 45 11.3% Total Pct 26.3% Row Pct 86.5% Col Pct	n = 15 3.8% Total Pct 8.8% Row Pct 60% Col Pct	n = 171 42.8% Total Pct
Severe WSL		n = 30 7.5% Total Pct 75% Row Pct 20.4% Col Pct	n = 6 1.5% Total Pct 15% Row Pct 11.5% Col Pct	n = 4 1% Total Pct 10% Row Pct 16% Col Pct	n = 40 10% Total Pct
Cavitation		n = 6 1.5% Total Pct 60% Row Pct 4.1% Col Pct	n = 1 0.3% Total Pct 10% Row Pct 1.9% Col Pct	n = 3 0.8% Total Pct 30% Row Pct 12% Col Pct	n = 10 2.5% Total Pct
Total	n = 176 44% Total Pct	n = 147 36.8% Total Pct	n = 52 13% Total Pct	n = 25 6.3% Total Pct	n = 400 100% Total Pct

**Table 4.8.4** Distribution of the 400 **left upper central incisors (21)** according to WSL-Change-Index scores at T2 and WSL-Index scores at T1. The number of patients (n), the percentages of patients from the total 400 teeth (Total Pct), the percentage of patients per row (Row Pct) and the percentages of patients per column (Col Pct) are given. Fields that do not apply are blank, “No WSL all times” marked in grey and improvements are highlighted in green.

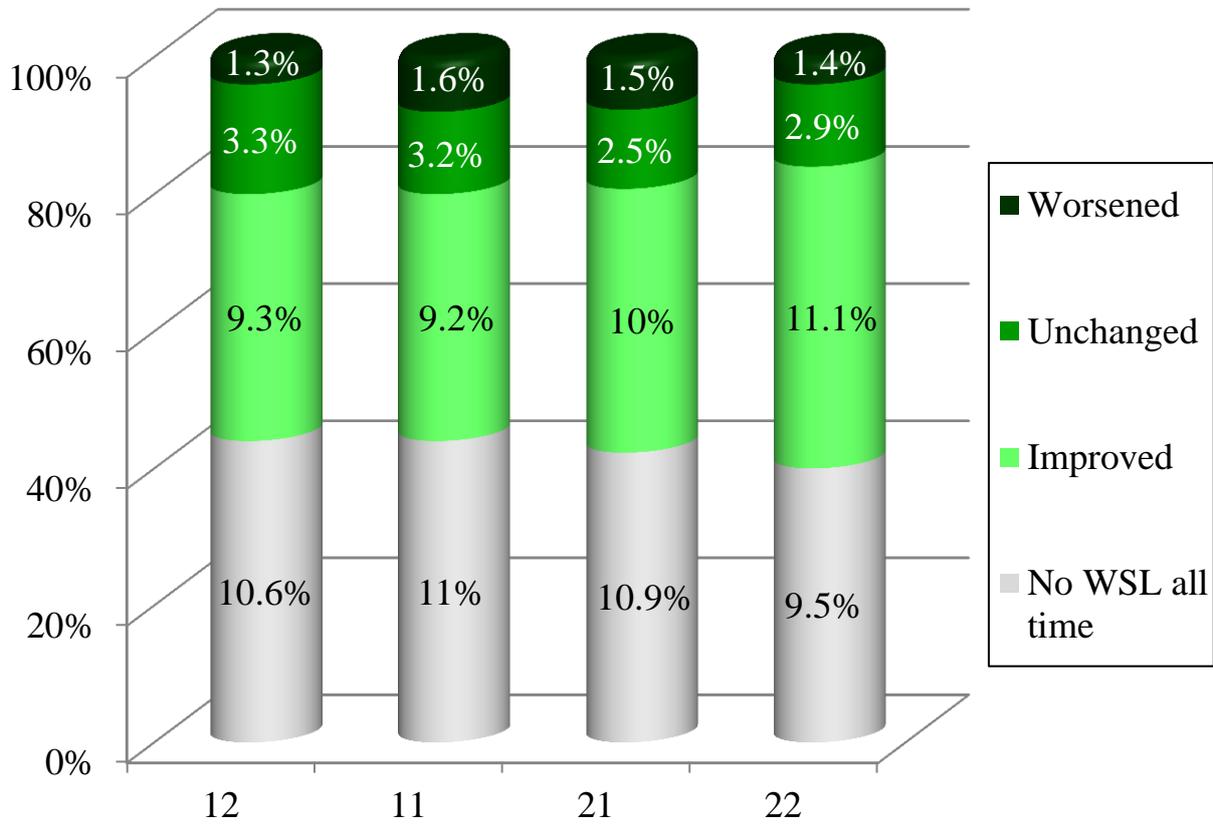
WSLC-Score (T2) WSL-Score (T1)	No WSL all times	Improved	Unchanged	Worsened	Total
No WSL	n = 175 43.8% Total Pct 98.3% Row Pct 100% Col Pct			n = 3 0.8% Total Pct 1.7% Row Pct 12.5% Col Pct	n = 178 44.5% Total Pct
Slight WSL		n = 123 30.8% Total Pct 71.5% Row Pct 76.4% Col Pct	n = 35 8.8% Total Pct 20.3% Row Pct 87.5% Col Pct	n = 14 3.5% Total Pct 8.1% Row Pct 58.3% Col Pct	n = 172 43% Total Pct
Severe WSL		n = 32 8% Total Pct 80% Row Pct 19.9% Col Pct	n = 4 1% Total Pct 10% Row Pct 10% Col Pct	n = 4 1% Total Pct 10% Row Pct 16.7% Col Pct	n = 40 10% Total Pct
Cavitation		n = 6 1.5% Total Pct 60% Row Pct 3.7% Col Pct	n = 1 0.3% Total Pct 10% Row Pct 2.5% Col Pct	n = 3 0.8% Total Pct 30% Row Pct 12.5% Col Pct	n = 10 2.5% Total Pct
Total	n = 175 43.8% Total Pct	n = 161 40.3% Total Pct	n = 40 10% Total Pct	n = 24 6% Total Pct	n = 400 100% Total Pct

**Table 4.8.5** Distribution of the 400 **left upper lateral incisors (22)** according to WSL-Change-Index scores at T2 and WSL-Index scores at T1. The number of patients (n), the percentages of patients from the total 400 teeth (Total Pct), the percentage of patients per row (Row Pct) and the percentages of patients per column (Col Pct) are given. Fields that do not apply are blank, “No WSL all times” marked in grey and improvements are highlighted in green.

WSLC-Score (T2) \ WSL-Score (T1)	No WSL all time	Improved	Unchanged	Worsened	Total
No WSL	n = 152 38% Total Pct 99.3% Row Pct 100% Col Pct			n = 1 0.3% Total Pct 0.7% Row Pct 4.3% Col Pct	n = 153 38.3% Total Pct
Slight WSL		n = 131 32.8% Total Pct 78.4% Row Pct 73.6% Col Pct	n = 29 7.3% Total Pct 17.4% Row Pct 61.7% Col Pct	n = 7 1.8 Total Pct 4.2% Row Pct 30.4% Col Pct	n = 167 41.8% Total Pct
Severe WSL		n = 39 9.8% Total Pct 63.9% Row Pct 21.9% Col Pct	n = 16 4% Total Pct 26.2% Row Pct 34% Col Pct	n = 6 1.5% Total Pct 9.8% Row Pct 26.1% Col Pct	n = 66 15.3% Total Pct
Cavitation		n = 8 2% Total Pct 42.1% Row Pct 4.5% Col Pct	n = 2 0.5% Total Pct 10.5% Row Pct 4.3% Col Pct	n = 9 2.3% Total Pct 47.4% Row Pct 39.1% Col Pct	n = 19 4.8% Total Pct
<b>Total</b>	n = 152 38% Total Pct	n = 178 44.5% Total Pct	n = 47 11.8% Total Pct	n = 23 5.8% Total Pct	n = 400 100% Total Pct



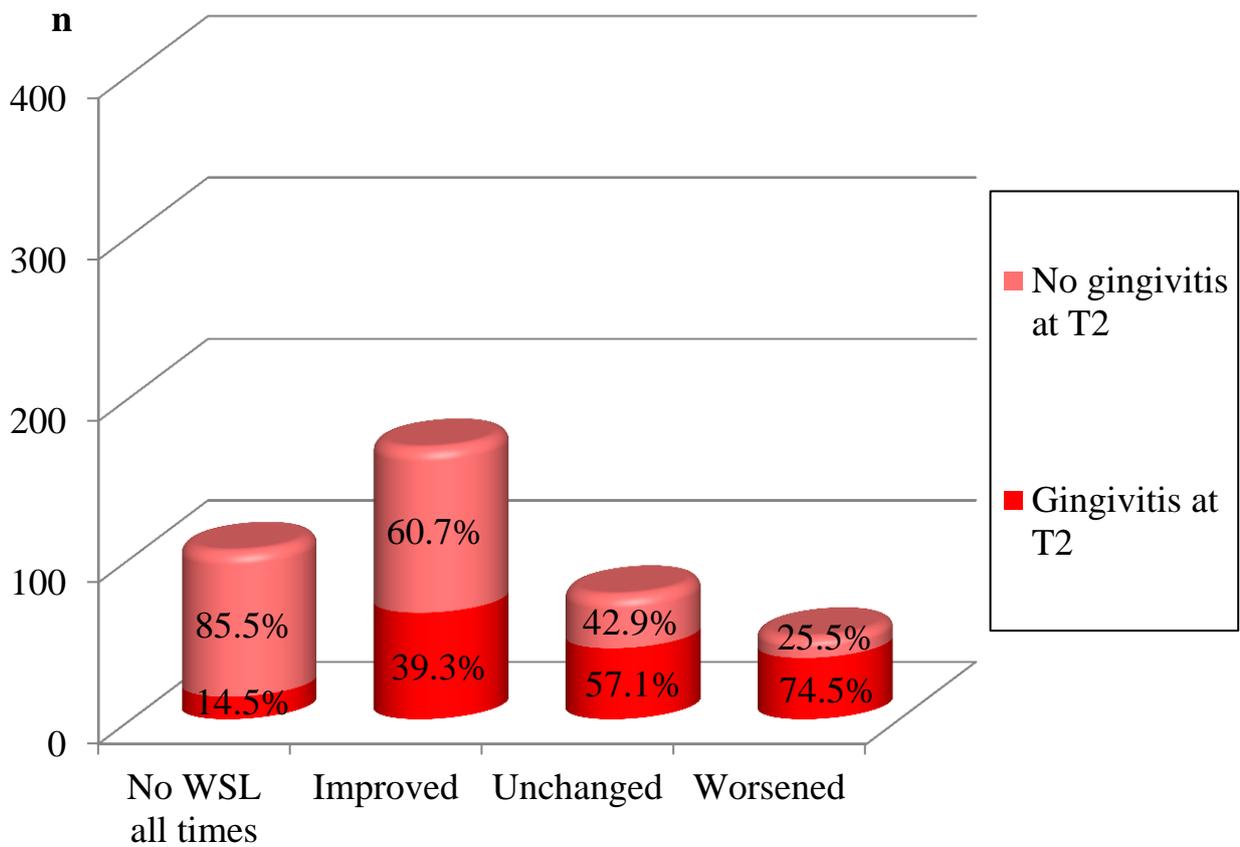
**Figure 4.8.1** Distribution of the 1600 teeth according to WSL-Change-Index scores at T2. The numbers (n) teeth are given.\* Please note: 8 teeth developed new WSL during the retention time.



**Figure 4.8.2** Frequency (%) of the WSLC-Index scores at T2 among the four UFT.

#### 4.9 Association between WSL change at T2 and Gingivitis at T2

Between the 104 patients that were WSL free all times, 85.5% did not show signs of gingivitis, whereas 14.5% the patients exhibited gingivitis after retention. On the other hand, from the 51 patients that showed deterioration of WSL after retention, 25.5% did not show signs of gingivitis, whereas 74.5% the patients exhibited gingivitis after retention (Figure 4.9.1). Thus, there was a clear trend for a higher prevalence of gingivitis in the groups with worsened WSL.



**Figure 4.9.1** Distribution of the 400 MB-patients (n) according to WSL-Change index and gingivitis at T2.

## 5 Discussion

### Study Population

This study was focused on MB-patients that were treated at the Department of Orthodontics of the Justus-Liebig-University starting from the year 1996, because at this time standardized general prophylactic measures and instructions were adopted for MB-patients. Patient inclusion ended with the year 2006, because afterwards prophylactic clinical trials were performed at the department, thus making these patients not comparable to patients receiving only standardized general instruction and fluoride prophylactic measures.

The number of patients included amounted to 400 MB-treated patients, which make it the largest study population compared to literature: Mizrahi, 1982 (269 patients); Gorelick et al., 1982 (192 patients); Artun and Brobakken, 1986 (120 patients), Pancherz and Mühlich, 1997 (108 patients); Gierer et al., 1988 (101 patients); Lovrov et al., 2007 (53 patients); Øgaard, 1989 (51 patients).

Females formed slightly more than half of the present study population (58%). This is in line with literature and reflects the ordinary situation in orthodontic practice (*Burden, 1995; Wheeler et al., 1994; Mandall, 1999*).

The selected inclusion criteria aimed at insuring an accurate and reliable evaluation with representative results for average MB patients. One of these inclusion criteria was that patients should not have received pervious MB-treatment to eliminate patients that presented WSL as a result of this treatment and thus tooth surfaces with increased WSL progression risk. Additionally, only the four UFT were considered since they are best visible and thus most reliably evaluable on standard intraoral slides. Besides, they are the aesthetically most valuable teeth in the patient's mouth (*Willmot, 2008*). Patients with dental structural abnormalities or frontal fillings, veneers or any other type of reconstructions on the labial surface of the four UFT at

any time during the examination period were not included, because these conditions might interfere with development risk, the evaluation and/or might cover already existing WSL.

Furthermore, the MB-treatment should have lasted for at least one year as this represents a normal average duration for a MB-treatment according to literature (*Richmond et al., 1993; Teh et al., 2000; Mavreas et al., 2008*). It was also considered, that the retention period should have lasted for at least one year, because it has been shown that most remineralization procedures take place during the first six months after treatment and beyond one year no major changes are seen (*Fehr et al., 1970; Artun and Thylstrup, 1989*). For the same reason all after treatment slides should have been taken directly or at the latest within one week of bracket deboning to assure, that no major remineralization had taken place since MB removal.

Axelsson (1999) reported that children between 11-14 years have a higher risk to develop caries and WSL during MB-treatment. For that reason, our patients were divided into three age groups sought to express mental maturation corresponding to puberty. It was observed, that about 61.2% of the MB-patients corresponded to the age group 12-16 years, which is due to the fact that the time interval 12-16 years goes along with the transition phase from late mixed dentition to permanent dentition where orthodontic treatment is most frequently carried out.

## Methods

In the literature, several authors have used intraoral color slides to assess demineralization before, during, or after orthodontic treatment (*Gorelick et al. 1982; Sonis et al., 1989; Adriaens et al., 1990; Mitchell, 1992; Turner, 1993; Trimpeneers et al., 1996; Marcusson et al., 1997; Pancherz and Mühlich, 1997; Millett et al., 1999; Wenderoth et al., 1999; Mattick et al. 2001*).

Willmot et al. (2000) reported that WSL could be measured reliably from photographic slides converted into digital images. A few years later Benson et al. (2005) reported that captured slides are as accurate and reproducible as direct digital camera images for the evaluation of enamel demineralization. In the present study, standardized intraoral photographic color slides were directly used to perform the retrospective visual examinations. This method has also been reported in literature as a reliable procedure (*Adriaens et al., 1990; Trimpeneers et al., 1996; Millett et al., 1999; Wenderoth et al., 1999*). In order to maximally reduce the method error and increase the WSL identification, the slides were projected at 1.1m x 1.6m size at the evaluation time.

Nevertheless, there is no doubt that a camera might record details differently than the naked eye. Flash reflections are one of the important slides limitations, which might complicate the WSL evaluation because of an overlapping with the WSL area, thus leading to a malestimation of the WSL which will most likely be an over- rather than an underestimation (Figure 5.1).

Even though, a standardization of the procedures with respect to the tooth wetness, lighting conditions and capture techniques is theoretically possible, this was not the case in the present study because of its retrospective nature. Although the same photographer took all slides routinely using a standardized technique throughout the whole study, minor imaging differences cannot be ruled out. Additionally minor deviations in the slide developmental process might have lead to different color intensity and saturation, which in turn could have



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**Figure 5.1** Flash reflection on the labial surface of incisors on an intraoral slide. Changes in the enamel structure in the affected area cannot be assessed reliably.

affected the accuracy of the evaluation (*Benson, 2008*). This basic problem will most likely have affected the differentiation between slight and severe WSL because even if a slide is over- or underexposed, yellowish or reddish the contrast between the brighter, whiter WSL areas and sound enamel remains distinguishable, thus allowing for the detection of presence or absence of WSL (Figure 5.2).

Three intraoral slides were used to assess each treatment time point. Frontal view slides were used for evaluating the upper two central incisors (11, 21) as they can be clearly seen in this projection. On the other hand, the two lateral teeth (12, 22) can be better inspected on the respective lateral side views because of the capture angle.



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**Figure 5.2** Four simulated color saturation and lightness conditions for the same intraoral slide. (1) Exaggerated yellowish tone, (2) exaggerated reddish tone, (3) exaggerated reduced color lightness, (4) exaggerated increased color lightness.

## Study parameters

Årtun and Brobakken (1986) described a quantitative evaluation system according to the WSL magnitude around brackets, however without considering the lesion depth. On the other hand, the WSL evaluation system developed by Banks and Richmond (1994) describes merely the localization of the demineralization and it is not commonly used in literature. Therefore, the semi-quantitative classification system by Gorelick et al. (1982) was the choice for the evaluation of the teeth before and after treatment in this study. It scores the size and the severity of WSL. In addition it is commonly used in literature. The slight modification of the index with respect to the original classification by Gorelick et al. (1982) used in the present study (WSL-Index scores 0-3 instead of 1-4) sought to simplify the scoring system.

The comparison system reported by Pancherz and Mühlich (1997) provides an easy way to describe the further course of the WSL during retention. The modification of the WSL-Change-Index used in the present study (addition of the category 0 = WSL free at all treatment times) was introduced to distinguish between teeth that were WSL-free at all time of the study and teeth that remain unchanged during the retention time.

Bacterial plaque accumulation on the tooth surfaces has long ago been reported to induce gingivitis (*Brandtzaeg, 1966*). Corbett et al. (1981) and Svanberg (1984) reported that increased plaque accumulation is closely related with gingivitis during MB-treatment, and is thus an indirect indicator for the oral hygiene situation. The photographic evaluation of the gingival redness and swelling performed in the present study has been reported to be a reliable and valid assessment method (*Smith, 2008*).

## Intra-examiner reproducibility and inter-examiner reliability

The intra-examiner reliability tests ranged between 70.2% - 95.1% for the WSL-Index and between 47.5%-92.7 for the WSL-Change-Index. According to Landis and Koch (1977), an intra-examiner agreement of 61%-80% represents a substantial agreement and above 80% an almost perfected intra-examiner agreement. The main study examiner had the highest intra-examiner agreement (average 93.9%), whereas the third examiner showed the lowest agreement (average 58.9%), which is most likely due to increased experience the study examiner gained during the preparation of his study. The inter-examiner reliability showed an agreement of 75.3% - 83.1% between the three examiners. Such moderate to high inter-examiner agreement rates indicate that the evaluation of WSL on projected intra-oral slides using WSL-Index and WSL-Change-Index was a reliable procedure.

Millett et al. (1999) compared the WSL formation around teeth bonded with glass ionomer cement and a resin adhesive. Their inter- and intra-examiner reliability ranged between moderate agreement (58%) to high substantial agreement (88%) and was thus, quite comparable with the present results. Nevertheless, Adriaens et al. (1990) evaluating WSL formation on buccal molar surfaces and Trimpeneers et al. (1996) studying the effect of a fluoride-releasing bonding system on WSL formation, both reported higher intra-examiner reliability (93%). In the Trimpeneers et al. (1996) study also the inter-examiner reliability was higher (91.5%).

## Results

### Before treatment

It could be shown in this study, that 32% of the patients exhibited WSL already before treatment. This prevalence lies within the range reported in literature by Lovrov et al. 2007 (15.5%), Gorelick et al. 1982 (24%) and Artun und Brobakken 1986 (40%) for untreated control groups. In contrast, Mizrahi (1982), Øgaard (1989) and Pancherz and Mühlich (1997) reported much higher WSL prevalences before treatment (70.4%-85%). The latter higher pre-treatment WSL prevalences are most likely due to the use of different WSL scoring systems and different WSL definitions, thus may be also including non-WSL enamel discolorations (dental fluorosis, nonfluoride traumatic opacities). Also the fact that the majority of the present affected patients showed slight lesions is in concordance with earlier findings (*Gorelick et al. 1982; Gierer et al. 1988; Øgaard, 1989; Lovrov et al., 2007*).

Considering the examined teeth in the present study, a before treatment WSL prevalence of 19.7% was seen. Pancherz & Mühlich (1997) found a comparable before treatment WSL prevalence of 24.9%, while percentages below 4% were reported by Gorelick et al. (1982) and Lovrov et al. (2007).

The prevalence of WSL before treatment did not differ between the gender groups, which matches earlier literature reports (*Gorelick et al., 1982; Mizrahi, 1982; Øgaard, 1989; Lovrov et al., 2007*).

While in the present study no relevant tendency for any of the four UFT to exhibit more WSL than any of the other teeth was seen, Gorelick et al. (1982) reported a higher WSL rate for the maxillary lateral (23 %) compared to the central incisors (8.4%).

Viewing the patients' distribution by WSL-Index scores and age groups revealed no significant difference with respect to the frequency / severity of WSL among the age groups. In contrast Pancherz and Mühlich (1997) found that young females under age 12 years exhibited more WSL before treatment than other MB-patients.

Before treatment, quite more than half (55%) of the WSL patients showed signs of gingivitis, while this was the case in only 34% of the WSL free patients. Thus, there seems to be a certain trend towards more WSL with poorer oral hygiene. However, the parameter “gingivitis” seems to be unable to clearly identify the risk patients, which is may be among others due to the fact that oral hygiene quality might change over time.

## After treatment

Changes in the WSL prevalence and / or the WSL incidence during MB-treatment have been reported in literature (*Gorelick et al., 1982; Mizrahi, 1982; Artun und Brobakken, 1986; Geiger et al., 1988; Øgaard, 1989; Mitchell, 1992; Wenderoth et al., 1999; Pancherz and Mühlich, 1997; Fornell et al., 2002; Zimmer et al., 2004; Lovrov et al., 2007*) using a variety of WSL evaluation methods, inclusion criteria and prophylactic measures. Thus, extreme caution has to be exerted when comparing the results of different studies. Therefore, in the following only studies with comparable evaluation methods and comparable prophylactic measures (fluoride toothpaste, fluoride mouthrinse plus conditionally high fluoride products) are cited for incidence / prevalence comparison.

The WSL incidence during MB-treatment amounted to 60.9%, thus resulting in a WSL prevalence of 73.5% after treatment. Pancherz and Mühlich (1997) reported new or increased WSL in 62% of the patients. Another study using the Gorelick et al. (1982) WSL-Index was published by Artun und Brobakken (1986), in which two study groups of MB patients from two different orthodontic practitioners showed higher WSL prevalence than an untreated reference group. Besides one MB-group both showed more WSL than the other (60% vs. 45%). The authors attributed this difference to varying follow-up periods (1 yr vs. 1.8 yrs, respectively) in the two groups. Gorelick et al. (1982) using the same WSL-Index but assessing all upper and lower teeth, reported a WSL incidence of 49.6% during MB-treatment. Thus, the present incidence and after treatment prevalence is unfortunately quite high compared to literature.

Many prophylactic measures have been introduced in the last decades aiming at the prevention of WSL during MB-treatment. Among the most common and effective measures are special oral hygiene instructions including a recommendation for the use of high fluoride toothpaste (*D'Agostino et al., 1988; Alexander and Ripa, 2000*), fluoride mouthrinse and high fluoride content products. The demineralization-inhibiting tendency of a daily use of fluoride rinse has been shown during MB-therapy (*Benson et al., 2004; Shafi, 2008*). Following the results from Pancherz and Mühlich (1997) exactly these supposedly most effective measures were adopted as a standard procedure at the Department in Giessen. However, the present results clearly indicate, that these general procedure are obviously insufficient to prevent WSL in an adequate percentage.

Zimmer (1999) studied the effect of various prophylaxis regimes to reduce WSL formation during MB treatment. He reported WSL incidence for patients between 0.4%-9.1%. However, these results are hard to compare to our findings due to the incorporation of comprehensive WSL prophylaxis and patients selection.

Considering the examined 1600 teeth, 57.4% of all upper front teeth exhibited WSL after treatment. Mizrahi (1982) using a different WSL-Index (Curzon and Spector, 1977) and analyzing all upper and lower teeth reported an even higher after treatment teeth WSL affection of 84%. On the other hand, Gorelick et al. (1982) reported only 12% WSL affected teeth after treatment. Pancherz and Mühlich (1997) found new or increased WSL in 29.4% of the teeth. A comparable percentage (24.9%) was published by Lovrov et al. (2007).

About two third of the WSL patients in the present study had mild lesions. Almost all other investigators that observed WSL after MB-treatment reported similar findings (*Gorelick et al., 1982; Gierer et al., 1988; Øgaard, 1989; Mitchel, 1992; Lovrov et al., 2007*).

Many authors (*Gorelick et al., 1982; Gierer et al., 1988; Artun und Brobakken, 1986*) noted that the upper lateral incisors showed a higher WSL prevalence and incidence than the upper centrals, however in the present study there was no evidence of such increased prevalence. Also gender showed no interrelation with WSL presence or absence. Similar findings could be seen in other studies by Gorelick et al. (1982), Mizrahi (1982), Øgaard, (1989) and Lovrov et al. (2007). Gorelick et al. (1982) and Mizrahi (1982) have however described a tendency for male patient to develop more severe WSL than female patients which matches our study findings.

Axelsson (1999) noted that children aged 11-14 years old were at a higher risk to develop WSL during MB-treatment, which resembles the slight tendency of our 12-16 years old patients to develop more WSL than the younger and older groups.

Even though it is often assumed (*Bishara and Ostby 2008*) that an increased MB-treatment time length in turn increases the risk for WSL development, in the present study similar active treatment times for both WSL and WSL free patients were seen.

After treatment, about half (49.7%) of the WSL patients had shown gingivitis before treatment, while about 84% of the WSL free patients did not exhibit gingivitis before treatment. This shows again that the presence of gingivitis before treatment is not a good parameter to judge the WSL risk. On the other hand, patients with good oral hygiene (no gingivitis) before treatment seem to have a reasonable chance to remain WSL free during treatment. The relation between oral hygiene parameters and the WSL risk have been analyzed earlier. Zimmer and Rottwinkel (2004) assessed prognostic risk factors for the development of WSL during MB treatment depending on a combination of oral hygiene parameters (plaque index, papillary bleeding index and number of pre-existing lesions). This WSL prognostic index showed a sensitivity of 75% and a specificity of 88%. Another oral hygiene parameter combination (clinical attachment level: sum of gingival recession and sulcus probing depth) was reported by Lovrov et al. (2007) to be closely correlated with the incidence of WSLs during MB-treatment.

## After retention

During the retention period, WSL free patients at T1 showed a very great tendency (98%) to remain WSL free. Two patients exhibited new WSL on all four UFT during the retention time (incidence rate 2%), thus confirming the observation from Øgaard (1989) that MB-treated patients retain a risk to develop WSL sometime after treatment.

In the present study, the majority (57.1%) of the WSL patients showed improvement during the retention period. This was specially truth for patients that had slight WSL at T1 (62.9% improvement). Øgaard (1989) reported that even 75% of the “small” WSL had regressed during the retention period. Artun and Thylstrup (1989) in their 3-years clinical study following the gradual regression and remineralization of WSL after treatment also observed similar findings. Pancherz and Mühlich (1997) reported that 19.1% of the patients that used to exhibit WSL after treatment were WSL-free 3 years after treatment, while 56.2% showed improvement and just 5.6% of the patients exhibited deterioration. In the present sample 5.1% of the WSL patients showed deterioration.

Looking at the individual teeth, similar findings could be observed: the majority (68.5%) of the teeth showed improvement and about 20% remained unchanged, while 10.8% worsened during the retention time. No relevant tendency of one of the four UFT to exhibit a higher percentage of WSL changes could be noticed. To my knowledge no such teeth specific findings have been reported in literature.

Whether looking at patients or teeth, it could clearly be seen that, as the WSL severity increased, the improvement rate decreased. This finding is of high clinical relevance, since after bracket debonding, the clinician has to decide whether to wait for spontaneous regression or improvement or to adopt adjunctive measures to enhance improvement or refer the patient for restorative measures. However, already Willmot (2008) stated, that WSL should not be immediately treated after removal of a fixed orthodontic appliance as they naturally reduce in size with no intervention.

Generally, the treatment of WSLs should begin with the most conservative measures possible, if such approaches do not resolve the problem and satisfy the patient more aggressive treatment measures may be applied. Topical application of high concentrated fluoride on WSL is considered by many clinicians as the first step in treatment (*Bishara and Ostby, 2008*). Theoretically, applying fluoride to demineralized enamel seems beneficial. Actually this is true for the most superficial layer of demineralized enamel. However, this has undesired effects leaving the deeper enamel crystals relatively unaffected and thus, locking the WSL under the hard newly mineralized enamel. Therefore, it seems advisable to first allow for a slow calcium and fluoride ion penetration into the WSL from saliva or through the application of lower concentrations of fluorides (*O'Reilly, 1987; Øgaard et al., 1988*). Using milk casein products (casein phosphopeptide amorphous calcium phosphate) suggested to potentially enhancing remineralization by allowing freely available calcium and phosphate ions to attach to enamel (*Reynolds, 1987; Reynolds, 1997; Reynolds et al., 2003*). It was also reported, that chewing gum promotes remineralization of enamel by increasing the salivary secretion (*Leach et al., 1989; Lijima et al., 2004; Shen et al. 2001*). Microabrasion techniques using 18% hydrochloric acid and pumice have also been described to treat WSL after MB treatment (*Welbury et al., 1993; Croll et al., 1994*) resulting in a mean WSL reduction of 83% (*Murphy et al., 2007*). The latter techniques are however, irreversible and should therefore only be used after the more conservative approaches have failed. Paris and Meyer-Lueckel (2009) described a new approach to mask WSL using low-viscosity light-curing resins “infiltrants” after erosion of the first enamel layer. The resin penetrates into the lesions’ micro-porosities driven by capillary forces and is subsequently hardened. The authors propose that this might be an alternative to microabrasion and restorative treatment treating WSL.

With respect to gender, it was noticed that females tended to show slightly more improved WSL compared to males. This could at least partly be due to the study observation that male patients tended to develop more severe WSL than female patients.

It was reported in literature (*Zimmer, 1998; Lovrov et al., 2007*) that the WSL incidence is closely related to oral-hygiene levels. Depending on the association between WSL and gingivitis at after retention it could be observed that patients that were WSL-free throughout all study times tended to show a lower gingivitis prevalence (13%) than all other study patients. This could most likely be due to good oral hygiene and patient’s cooperation that was main-

tained during and after orthodontic treatment. For the other groups, however, a gradual increase in the gingivitis prevalence with increased to WSL-Change index scores was seen (improved = 39.3%, unchanged = 57%, worsened = 74%). This observation could be a hint that the further changes of WSL during retention might be closely related with oral hygiene.

## 6 Conclusion

Using only general prophylactic measures, new WSL developing on the upper front teeth during MB treatment remain to be a frequent undesired side-effect affecting 60.9% of the patients and counteracting our efforts for clinical excellence. Thus, improved prophylactic measures possibly including more in office controls are required.

In case WSL have developed during treatment it can be expected that the majority of the WSL will improve during the retention period. In this context patients with mild WSL and good oral hygiene have a better chance for improvement.

## 7 Summary

The present study aimed to investigate the incidence and further course of White Spot Lesions (WSL) during and after multibrackets appliance (MB) treatment.

All former MB-patients finishing orthodontic treatment at the University of Giessen between 1996 and 2006 were screened. The first 400 patients (168 male, 232 female) meeting the inclusion criteria - all upper front teeth (UFT) fully erupted and visible on before treatment photographs, no fillings or structural abnormalities, duration MB treatment  $\geq 1$  year, retention period  $\geq 1$  year - were selected. The average age of the patients was 13.7 years (SD 3.5) and the average MB treatment time 1.9 years (SD 3.6). A modification of the White Spot Index by Gorelick et al. (1982) was used to evaluate the labial surface of the four front teeth in the upper incisor area on intra-oral photos before (T0), after treatment (T1) and after the end of retention (T2).

The results revealed the following:

- Before treatment 32.3% of the patients exhibited WSL on 19.7% of the UFT.
- After MB treatment 73.5% of the patients and 57.4% of the UFT presented WSL.
- The incidence of WSL during MB treatment amounted to 60.9% of the patients.
- The majority of the UFT (41.2%) had mild lesions while the remaining UFT were affected severely with (3.8%) or without (12.4%) cavitations at T1.
- Only 26.5% of the patients were free of WSL both at T0 and at T1.
- After the retention phase the majority of the lesions (68.4%) were improved, 20.7% were unchanged and 10.9% had worsened.
- Male WSL-patients tended to show more severe WSL than females.
- There was a tendency for an increased WSL development during the adolescent compared to pre- and post-adolescent age groups.

It was concluded, that using only general prophylactic measures, new WSL developing on the UFT during MB treatment remain to be a frequent undesired side-effect affecting 60.9% of the patients counteracting our efforts for clinical excellence.

## 8 Zusammenfassung

Ziel der vorliegenden Arbeit war es, die Inzidenz und weitere Entwicklung von White Spot Läsionen (WSL) während Multibracket-Behandlung (MB) zu untersuchen.

Aus allen Patienten, die zwischen 1996 und 2006 eine MB-Behandlung an der Universität Gießen abgeschlossen hatten, wurden die ersten 400 Patienten (168 männlich, 232 weiblich), die die Einschlusskriterien erfüllten ausgewählt. Einschlusskriterien: alle vier oberen Frontzähne (OK-FZ) vor der Behandlung vollständig durchgebrochen, keine Füllungen oder Strukturabnormitäten, MB-Behandlungszeit  $\geq 1$  Jahr, Retentionsphase  $\geq 1$  Jahr. Das durchschnittliche Alter der Patienten vor Behandlung betrug 13,7 Jahre (SD 3,5) und die durchschnittliche MB-Behandlungszeit 1,9 Jahre (SD 3,6). Eine Modifizierung des WSL-Index nach Gorelick et al. (1982) wurde verwendet, um die labiale Oberfläche der OK-FZ anhand intraoraler Fotos vor Behandlung (T0), nach Behandlung (T1) und am Ende der Retentionsphase (T2) zu bewerten.

Die Studie führte zu den nachfolgend gelisteten Ergebnissen:

- Vor der Behandlung wiesen 32,3% der Patienten bzw. 19,7% der OK-FZ WSL auf.
- Nach der MB-Behandlung hatten 73,5% der Patienten bzw. 57,4% der OK-FZ WSL.
- Die WSL-Inzidenz während MB-Behandlung betrug 60,9% der Patienten.
- Die Mehrzahl der OK-FZ (41,2%) hatten bei T1 leichte WSL, während ein hoher Schweregrad mit/ohne Kavitationen bei 3,8% respektive 12,4% der OK-FZ vorlag.
- Nur 26,5% der Patienten hatten sowohl bei T0 als auch bei T1 keine WSL.
- Nach der Retentionsphase hatten sich die Mehrzahl der Läsionen (68,4%) verbessert, 20,7% blieben unverändert und 10,9% verschlechterten sich.
- Männliche WSL-Patienten zeigten mehr schwergradige WSL als die weiblichen.
- Tendenziell entwickelten adolescente Patienten mehr WSL als prä- und postadoleszente Individuen.

Trotz verbesserter allgemeiner prophylaktischer Maßnahmen bleiben WSL, die sich während der MB-Behandlung an den oberen Frontzähnen entwickeln, eine häufige unerwünschte Ne-

benwirkung die 60.9% der Patienten betrifft und somit unserem Streben nach klinischer Exzellenz widerspricht.

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## 10 Attachment

**CASE DOUMENTARY SHEET**

Study subject No. ....

Gender : M  / F 

Date of birth : .....,.....,.....

**Treatment data**

Brackets in	.....
Brackets out	.....
End of Retention	.....

**Before treatment (T0)**

Photo date: .....,.....,.....

WSL-Index

Tooth	<b>12</b>	<b>11</b>	<b>21</b>	<b>22</b>
WSL Scoring				
Gingival inflam.				

**After treatment (T1)**

Photo date: .....,.....,.....

WSL-Index

Tooth	<b>12</b>	<b>11</b>	<b>21</b>	<b>22</b>
WSL Scoring				

**After retention (T2)**

Photo date: .....,.....,.....

WSL-change-Index

Tooth	<b>12</b>	<b>11</b>	<b>21</b>	<b>22</b>
WSL Scoring				
Gingival inflam.				

## 11 Publication

The present study was published in two abstract:

M Enaia, S Ruf : White Spot Lesions during multibracket appliance treatment – a challenge for clinical excellence. Eur J Orthod 2009; 31: e53-e54.

M. Enaia, N. Bock, S. Ruf: Entkalkung während Multibracket-Behandlung - ein ungelöstes Problem. J Orofac Orthop 2009; 70: 446.

In addition, the present study was also published as poster in the:

85th Congress of European Orthodontic Society 2009.

82<sup>th</sup> Annual Conference of the Deutsche Gesellschaft für Kieferorthopädie 2008.

The study manuscript have been published as an Online-only Article in the American Journal of Orthodontics and Dentofacial Orthopedics.

M Enaia, S Ruf : White Spot Lesions during multibracket appliance treatment – a challenge for clinical excellence, July 2011 (volume 139, no. 1)

**M Enaia, S Ruf : White Spot Lesions during multibracket appliance treatment – a challenge for clinical excellence. Eur J Orthod 2009; 31: e53-e54.**

138 WHITE SPOT LESIONS DURING MULTIBRACKET APPLIANCE TREATMENT – A CHALLENGE FOR CLINICAL EXCELLENCE

M Enaia, S Ruf, Justus Liebig University of Giessen, Germany

AIM: To investigate the incidence and course of white spot lesions (WSL) during multibracket appliance (MB) treatment.

SUBJECTS AND METHOD: All former MB patients finishing orthodontic treatment between 1996 and 2006 were screened. The first 400 patients (168 male, 232 female) meeting the inclusion criteria, all upper front (UFT) fully erupted and visible on before treatment photographs, no fillings or structural abnormalities, duration MB treatment >1 year, retention period >1 year, were selected. The average age of the patients was 13.7 years (SD 3.5) and the average MB treatment time 1.9 years (SD 3.6). A modification of the White Spot Index (Gorelick *et al.*, 1982) was used to evaluate the labial surface of the four anterior teeth in the upper incisor area on intraoral photographs before (T0), after treatment (T1) and at the end of retention (T2).

RESULTS: At T0 32.3 per cent of the patients exhibited WSL on 19.7 per cent of the UFT. After MB treatment 73.5 per cent of the patients and 57.4 per cent of the UFT presented WSL. Thus, the incidence rate for WSL (T1-T0) was 41.2 per cent of the patients and 37.7 per cent of the UFT. The majority of the UFT (41.2%) had mild lesions while the remaining UFT were severely affected with (3.8%) or without (12.4%) cavitations at T1. Only 26.5 per cent of the patients were free of WSL at both T0 and at T1. At T3, 57.9 per cent of the UFT presented WSL, however the majority of the lesions (68.4%) were improved, 20.7 per cent were unchanged and 10.9 per cent had worsened. No gender differences were found. There was a tendency for increased WSL development during adolescence compared with the pre- and post-adolescent age groups.

e53

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CONCLUSIONS: Despite improved prophylactic measures, WSL developing on the upper anterior teeth during MB treatment is a frequent undesired site-effect affecting about 40 per cent of the patients and counteracting efforts for clinical excellence.

**M. Enaia, N. Bock, S. Ruf: Entkalkung während Multibracket-Behandlung  
- ein ungelöstes Problem. J Orofac Orthop 2009; 70: 446.**

**P 75**

J Orofac Orthop 2009;70: 446

**Entkalkung während Multibracket-Behandlung –  
ein ungelöstes Problem**

M. Enaia, N. Bock, S. Ruf

*Poliklinik für Kieferorthopädie, Justus-Liebig-Universität Giessen*

**Ziel:** Untersuchung der Inzidenz und der weiteren Entwicklung von White Spot Lesions (WSL) während Multibracket (MB) Behandlung.

**Material und Methode:** Aus allen Patienten, die zwischen 1996 und 2006 eine MB-Behandlung an der Universität Giessen abgeschlossen hatten, wurden die ersten 400 Patienten (168 männlich, 232 weiblich), die die Einschlusskriterien erfüllten ausgewählt. Einschlusskriterien: alle vier oberen Frontzähne (OK-FZ) vor der Behandlung vollständig durchgebrochen, keine Füllungen oder Strukturabnormitäten, MB-Behandlungszeit mindestens 1 Jahr, Retentionsphase mindestens 1 Jahr. Das durchschnittliche Alter der Patienten vor Behandlung betrug 13,7 Jahre (SD 3,5) und die durchschnittliche MB-Behandlungszeit 1,9 Jahre (SD 3,6). Eine Modifizierung des WSL-Index nach Gorelick et al. (1982) wurde verwendet, um die labiale Oberfläche der OK-FZ anhand auf 1,1 m × 1,6 m projizierten intraoralen Fotos vor Behandlung (T0), nach Behandlung (T1) und am Ende der Retentionsphase (T2) zu bewerten.

**Ergebnisse:** Vor der Behandlung wiesen 32,3 % der Patienten bzw. 19,7 der OK-FZ WSL auf. Nach der MB-Behandlung hatten 73,5 % der Patienten bzw. 57,4% der OK-FZ WSL. Somit betrug die WSL-Inzidenz während MB-Behandlung (T1-T0) 41,2% der Patienten bzw. 37,7% der OK-FZ. Die Mehrzahl der OK-FZ (41,2%) hatten bei T1 leichte WSL, während ein hoher Schweregrad mit / ohne Kavitationen bei 3,8% respektive 12,4% der OK-FZ vorlag. Nur 26,5% der Patienten hatten sowohl bei T0 als auch bei T1 keine WSL. Nach der Retentionsphase wiesen noch 57,9% der OK-FZ WSL auf. Die Mehrheit der erkrankten Zähne (68,4%) verbesserten sich, 20,7% blieben unverändert und 10,9 % verschlechterten sich. Geschlechts-unterschiede lagen nicht vor.

**Schlussfolgerung:** Trotz verbesserter prophylaktischer Maßnahmen bleiben WSL, die sich während der MB-Behandlung u. a. an den oberen Frontzähnen entwickeln, eine häufige unerwünschte Nebenwirkung die gut 40 % der Patienten betrifft.

85<sup>th</sup> Congress of European Orthodontic Society 2009-Poster



## White Spot Lesions during multibracket appliance treatment – a challenge for clinical excellence

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### Conclusion

Despite improved prophylactic measures White Spot Lesions developing on the upper front teeth during multibracket appliance treatment remain to be a frequent undesired side-effect affecting about 60.9% of the patients.

### Aim

To investigate the incidence and further course of White Spot Lesions (WSL) during multibracket (MB) appliance treatment.



### Material & Methods

All former MB-patients finishing orthodontic treatment at the University of Giessen between 1996 and 2006 were screened. The first 400 patients (168 male, 232 female) meeting the inclusion criteria - all upper front teeth (UFT) fully erupted and visible on before treatment photographs, no fillings or structural abnormalities, MB-treatment duration > 1 year, retention period > 1 year - were selected. The average age of the patients was 13.7 years (SD 3.5) and the average MB-treatment time 1.9 years (SD 3.6). A modification of the WSL-Index by *Gorelick et*

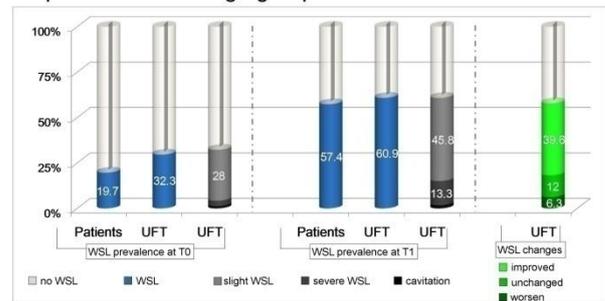
*al.*<sup>1</sup> was used to evaluate the labial surfaces of the UFT on intra-oral photos projected at an image size of 1.1m x 1.6m. The WSL were assessed before (T0), after treatment (T1) and after the end of retention (T2).



### Results

Before treatment 32.3% of the patients exhibited WSL on 19.7% of the UFT. After MB-treatment 73.5% of the patients and 57.4% of the UFT presented WSL. Thus, the incidence rate for WSL (T1-T0) amounted to 41.2% of the patients and 37.7% of the UFT. The majority of the UFT (41.2%) had mild lesions while the remaining UFT were affected severely with (3.8%) or without (12.4%) cavitations at T1. Only 26.5% of the patients were free of WSL both at T0 and T1. After the retention phase 57.9% of the UFT presented WSL, however the majority of the lesions (68.4%) were improved, 20.7% were unchanged and 10.9% had worsened. No gender differences were

found. There was a tendency for an increased WSL-development during the adolescent compared to the pre- and post-adolescent age groups.



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## Entkalkung während Multibracket-Behandlung - ein ungelöstes Problem

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### Schlussfolgerung:

Trotz verbesserter prophylaktischer Maßnahmen bleiben White Spots, die sich während einer Multibracket-Behandlung u. a. an den oberen Frontzähnen entwickeln, eine häufige unerwünschte Nebenwirkung, die gut 60.9 % der Patienten betrifft.

### Ziel

Untersuchung der Inzidenz und weiteren Entwicklung von White Spot Lesions während MB-Behandlung.



### Material und Methode

Aus allen Patienten, die zwischen 1996 - 2006 eine MB-Behandlung an der Universität Giessen abgeschlossen hatten, wurden die ersten 400 Patienten (168 männliche, 232 weibliche), die die Einschlusskriterien erfüllten ausgewählt. Einschlusskriterien: alle vier obere Frontzähne (OK-FZ) vor der Behandlung vollständig durchgebrochen, keine Füllungen oder Strukturabnormitäten, MB-Behandlungszeit  $\geq$  1 Jahr, Retentionsphase  $\geq$  1 Jahr. Das durchschnittliche Alter der Patienten vor Behandlung betrug 13,7 Jahre (SD 3,5) und die durchschnittliche MB-Behandlungszeit 1,9 Jahre (SD 3,6). Eine Modifizierung

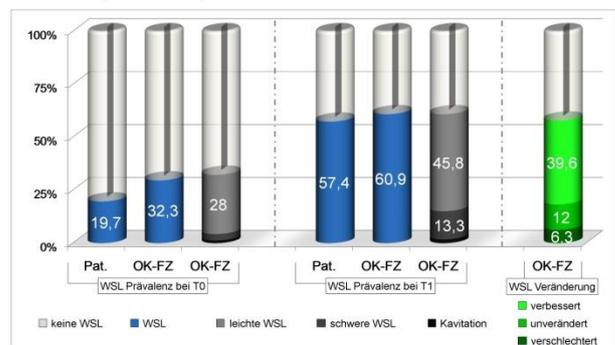
des White Spot Lesion (WSL) Index nach *Gorelick et al.* (1982) wurde verwendet, um die Labialfläche der OK-FZ auf 1,1m x 1,6m gross projizierten intraoralen Fotos vor Behandlung (T0), nach Behandlung (T1) und am Ende der Retentionsphase (T2) zu bewerten.



### Ergebnisse

Vor der Behandlung wiesen 32,3% der Patienten bzw. 19,7 der OK-FZ WSL auf. Nach der Behandlung hatten 73,5% der Patienten bzw. 57,4% der OK-FZ WSL. Somit betrug die WSL-Inzidenz während MB-Behandlung (T1-T0) 41,2% der Patienten bzw. 37,7% der OK-FZ. Die Mehrzahl der OK-FZ (41,2%) hatten bei T1 leichte WSL, während ein Schweregrad mit / ohne Kavitationen bei 3,8% respektive 12,4% der OK-FZ vorlag. Nur 26,5% der Patienten hatten sowohl bei T0 als auch bei T1 keine WSL. Nach der Retentionsphase wiesen noch 57,9% der OK-FZ WSL auf. Die Mehrheit der erkrankten Zähne (68,4%) hatten sich verbessert, 20,7% blieben unverändert und 10,9% verschlechterten sich. Geschlechtsunterschiede lagen nicht

vor. Tendenziell entwickelten adolescente Patienten mehr WSL als prä- und postadoleszente Individuen.



## 12 Acknowledgement

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**Der Lebenslauf wurde aus der elektronischen  
Version der Arbeit entfernt.**

**The curriculum vitae was removed from the  
electronic version of the paper.**