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The Influence of Fixed Orthodontic Appliances on Halitosis

A Prospective Clinical Study

Keywords: halitosis, fixed orthodontic appliances, dental hygiene

Summary Halitosis is a widely spread condition. There are numerous causes. The aim of this study was to investigate the influence of fixed orthodontic appliances on the occurrence of halitosis.

55 patients in an orthodontic practice were monitored at three points in time after application of orthodontic appliance (T1: immediately after application, T2: 4 weeks after application, T3: 3 months after application). Monitoring included patient self-evaluation, plaque index, tongue coating index and organoleptic measurement. The subjective parameters taste, dry mouth and breath odor did not show statistical differences. However, with the presence of fixed orthodontic appliances, confidence when performing dental hygiene decreased statistically significantly ($p=0.003$). Additionally, the tongue coating index showed a statistically significant difference between T1 and T2 ($p=0.012$) as well as T1 and T3 ($p>0.001$). Analogous results were found for organoleptic measurement (T1 and T2 [$p=0.002$]; T1 and T3 [$p<0.001$]) and plaque index (T1 and T2/T3 [$p<0.001$]).

Fixed orthodontic appliances lead to a statistically significant increase of the plaque and tongue coating indices. A statistically significant increase was also observed with organoleptic measurement scores. The suspected positive correlation between halitosis and fixed orthodontic appliances was confirmed. Halitosis can be an important indicator of oral health during orthodontic treatment and can serve as a motivating factor for adequate patient oral health care maintenance.

Introduction

Healthy human breath exhibits a slightly sweet, generally not discernible smell under normal circumstances. Factors such as time of day, salivation, oral flora, and food intake (Rosenberg & McCulloch 1992) or dental hygiene can change breath intensity.

Halitosis denotes the offensive smell of breath. Synonyms for bad breath are foetor ex ore, oral malodor or offensive breath. Halitosis combines various pathologies. A distinction is made between real halitosis (distinctive bad breath, intensity clearly above socially accepted degrees), which can be physiological or pathological, pseudo-halitosis (bad breath not discernible by others, improved situation after patient information) and halitophobia (bad breath not discernible by others, no improvement of situation after patient information) (Yaegaki & Coil 2000).

Causes for halitosis can be oral or non-oral. Various studies show that 85–90% of all cases exhibit bacterial decomposition of organic material in the oral cavity as a cause for halitosis (Amir et al. 1999, Delanghe et al. 1996, Delanghe et al. 1997, Delanghe et al. 1999, Rosenberg & Leib 1997). The metabolism of gram-negative bacteria which subsist mainly on protein containing sulfurous amino acids (methionine, cysteine and cystine) produces volatile sulfur compounds (VSC), which take a central role in the development of halitosis (Persson et al. 1990, Preti et al. 1992, Rosenberg & McCulloch 1992, Yaegaki & Sanada 1992, van Steenberghe et al. 2001). 60% of all oral microorganisms are situated on the tongue (Gilmore & Bashkar 1972, Jacobson et al. 1973, Gilmore et al. 1973, Yaegaki & Sanada 1992, De Boever & Loesche 1995), which represents the primary source of bacteria in the oral cavity and the main cause of halitosis. Quantitative measurements confirmed the prominent significance of the microflora of the tongue for the eti-

ology of halitosis (BOSY ET AL. 1994, SHARMA ET AL. 1999, WALER 1997, YAEGAKI & SANADA 1992). Extraoral causes are uncommon and include otorhinolaryngological changes (specifically colds), general systemic conditions, use of medication, consumption of tobacco, particular dietary habits, as well as smells originating in the gastrointestinal tract (LANG & FILIPPI 2004). Factors favoring halitosis are tongue coating, periodontal diseases, large cavities with open root canals, pericoronitis, conditions affecting the oral mucous membrane, food impaction, neglected dentures, reduced salivation, and oral breathing (VAN DEN BROEK ET AL. 2007).

Various studies have investigated the influence of orthodontic appliances on the level of bacteria in the oral cavity. The side effects described include decalcification, white spots, cavities (GLASSPOOLE ET AL. 2001, BENSON ET AL. 2003, 2005), periodontal reactions (ELLIS & BENSON 2002), and gingivitis (LEE ET AL. 2005). Fixed orthodontic appliances favor the accumulation of plaque, therefore increasing the risk of white spot lesions during treatment (MITCHELL 1992). The design and surface structure of the orthodontic appliance, as well as the composite, influence plaque retention (GWINNETT & CEEN 1979, SVANBERG ET AL. 1984). The manner of mounting the orthodontic wire on the brackets also plays a role (FORSBERG ET AL. 1991). The obvious question whether there is a direct causal relationship between orthodontic appliances – specifically fixed appliances – and halitosis has not been investigated to date. An exception is the study by BABACAN ET AL. (2011), which found a causal relationship by halimeter measurements and plaque and gingival indices. However, no organoleptic measurements were included in the investigation.

The aim of this study was to investigate whether fixed orthodontic appliances encourage the development of halitosis. A self-evaluating interview was conducted as a basis for the investigation. For the purposes of objectification, organoleptic measurements as well as plaque and tongue coating indices were recorded.

Materials and methods

For ethical reasons, patients or the parents of patients were informed in writing of the aim and content of this study as well as the protection of data privacy. Data was collected during regular orthodontic consultations. Participation in the study was voluntary and patients were entitled to withdraw from the study at all stages.

All subjects, or their parents in the case of minors, confirmed in writing that they had been sufficiently informed of all details of the study, and that their questions had all been clarified. The prospective clinical study included 62 patients which were in orthodontic treatment between February and May 2008. All patients with plans to have fixed orthodontic appliances mounted in this period were asked to participate in the study to ensure random subject selection. Good general health was a prerequisite for participation. Patients who had been ill or medicated four weeks prior to the study were not included. Additionally, no medication was allowed throughout the duration of the study. No smokers were included in the sample.

In a first step, appliances were installed in one jaw only, whereas the second jaw was provided with brackets after a period of familiarization. All subjects received identical instructions for dental hygiene after application concerning the use of toothbrush (3 times daily for 3 minutes) as well as interdental brushes and floss.

Prior to the study, the examiner was carefully trained. The training of the examiner was conducted by an experienced practitioner of halitosis consultations at the University of Basel.

The brackets (SPEED System™, Ontario, Canada) were applied to all permanent teeth from 6-year molar to 6-year molar. At three time intervals (T1: immediately after application, T2: 4 weeks after application, T3: 3 months after application), patients were interviewed and clinically examined at the same time of day by the same examiner. The measurement values of T1 served as control.

Interview and clinical parameters

The questionnaire comprised five questions, where questions 2 and 3 were only asked at T2 as they are aimed at perceived changes since application (Tab. I).

Tongue coating was recorded according to the Miyazaki tongue coating index (1995) (Tab. II). Evaluation of dental hygiene was established with the Silness and Löe plaque index (SILNESS & LÖE 1964) (Tab. II). The jaw undergoing subsequent bonding was indexed and the evaluation was performed without coloring, visually, and with the help of a probe. Organoleptic measurements with the 1-2-3 method included an evaluation of the perceived smell intensity while counting from 1 to 10 in different distances from the origin of the smell (SEEMANN 2001) (Tab. II).

Statistics

Descriptive analysis includes the constant parameters mean age, minimum, maximum and standard deviation. Categorical parameters were cross-tabulated with number of cases and percentage values. P-values were calculated with Fisher's exact test and $p < 0.05$ set for level of significance. Logistic regression was used for comparing binary variables between measuring times. Multinomial logistic models were used for variables exhibiting multiple answers. Statistical calculations were performed with the statistical package R (The R Foundation for Statistical Computing, Version 2.9.2).

Results

Of the initial 62 patients, six did not show for follow-up appointments and one person was excluded from the study for coming to the appointment while ill. Finally, the data of 55 patients (30 female, 25 male; age: $\bar{x}=15.13$, 9- 27, $SD=4.15$) was analyzed.

Tab. I 5 interview questions

Question	Answers
1. Do you notice a bad taste in your mouth?	No/Yes
2. Do you feel a degree of dry mouth?	No/Yes
3. Did you (parents) notice an increase in breath odor?	No/Yes
4. How often do you brush your teeth?	Once and 1–2 times Twice and 2–3 times ≥ 3 times
5. How confident do you feel while performing oral hygiene?	Confident Moderately confident Insecure

Tab. II 3 clinical parameters	
Miyazaki tongue coating index	
Grade 0	No visible coating
Grade 1	Less than a third of tongue dorsum is covered
Grade 2	Less than two thirds of tongue dorsum is covered
Grade 3	More than two thirds of tongue dorsum is covered
Organoleptic measurement *(1-2-3 method)*	
Grade 0	No smell discernible from 10 cm
Grade 1	Smell discernible from 10 cm
Grade 2	Smell discernible from 30 cm
Grade 3	Smell discernible from 1 m
Silness and Löe plaque index	
Grade 0	No plaque discernible visually or using the probe
Grade 1	Not visible thin coating of plaque which is only visible after using the probe
Grade 2	Moderate accumulation of plaque, visible with the naked eye, but not filling interdental space
Grade 3	Abundance of plaque, filling interdental space

Interview

After application of the orthodontic appliances, no statistically relevant bad taste was subjectively perceived (T1: 14/55; T2: 17/55; T3: 20/55) ($p=0.487$).

Equally not statistically relevant was the subjectively perceived dry mouth and breath odor ($p=1$). Approximately a third of the subjects (17/55) felt an increasingly dry mouth since wearing brackets, and more than a quarter of the subjects (15/55) noticed a subjective increase of breath odor four weeks after application of the orthodontic appliances.

The frequency of brushing teeth did not significantly change within the time frame of the three measurements ($p=0.325$). At T1, 31 of 55, and at T2, 28 of 55 patients indicated to brush teeth *twice and two to three times* daily. At T3, 28 of 55 participants brushed teeth ≥ *three times*.

A statistically relevant deterioration was noted for the parameter "confidence when performing oral hygiene" ($p=0.003$). Prior to application, 44 of 55 patients felt *confident* with brushing teeth. Over the course of the study, this value consistently decreased, with plus 11 subjects answering *moderately confident* at T1, plus 19 at T2 and 28 at T3 (Fig. 1).

Clinical parameters

After application of orthodontic appliances, a statistically significant increase in tongue coating was recorded on the tongue coating index. Over the course of the study, the number of patients exhibiting grade 0 decreased, whereas the number of patients exhibiting grade 2 increased (Fig. 2, Tab. III). A statistically significant difference between T1 and T2 ($p=0.012$) and T1 and T3 ($p<0.001$) was recorded.

Organoleptic measurements showed continuously decreasing values for grade 0 and a continuous increase for grades 1 and 2 (Fig. 2, Tab. III). A statistically significant difference between T1 and T2 ($p=0.002$) and T1 and T3 ($p<0.001$) was recorded.

A statistically significant difference was found in the plaque index variable between T1 and T2 ($p<0.001$) as well as T1 and T3 ($p<0.001$). Whereas no plaque was found with 40 of 55 patients at T1, that value decreased over time, mostly in favor of grade 1 (Fig. 2, Tab. III).

Discussion

The influence of fixed orthodontic appliances on halitosis and oral hygiene was investigated based on a combination of self-evaluation, organoleptic measurement, and intraoral diagnosis. The interview was concerned with subjective factors and oral hygiene habits, whereas the subjects' self-evaluation of bad taste, degree of dry mouth, and breath odor were only considered as complementary information to the clinical data. Self-evaluation considering breath odor is often not correct (Miyazaki et al. 1995, Loesche et al. 1996, Bornstein et al. 2009). It is difficult to correctly evaluate one's own breath and often a negative self-evaluation cannot be confirmed with objective measuring methods (Hughes & McNab 2008).

Professional evaluation of halitosis is generally performed with a five-point scale (Rosenberg et al. 1991a). A division in three degrees of severity is however sufficient for the daily practice (Seemann 2001). For this reason, this study utilized

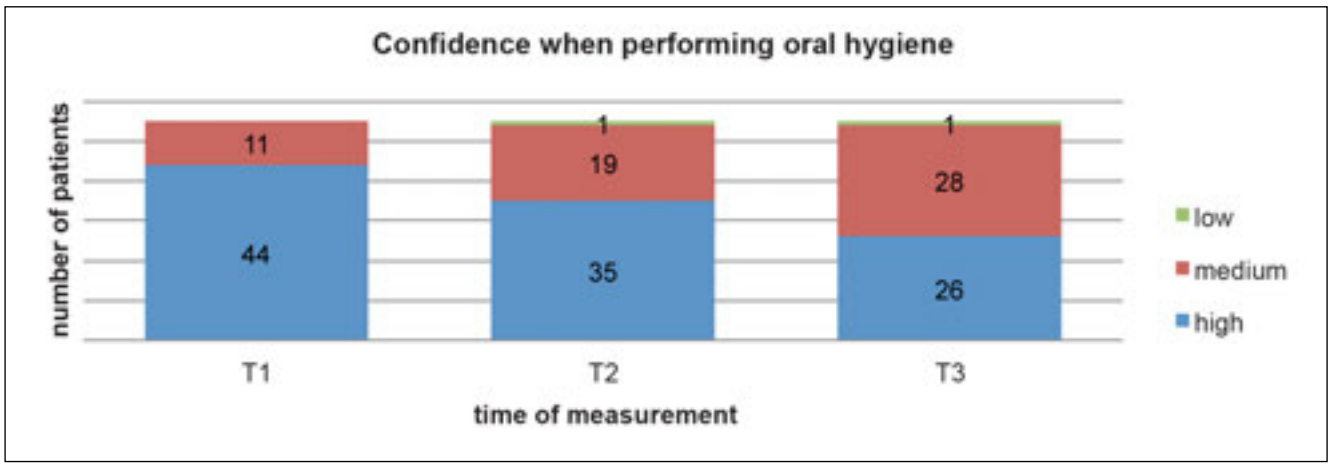

Fig. 1 Results regarding confidence when performing oral hygiene derived from interviews at three times (T1: immediately after application, T2: 4 weeks after application, T3: 3 months after application)

Tab. III Parameters tongue coating index (TCI)/organoleptic measurement (OM)/plaque index (PI) at different times *(T1/T2/T3)*

	Grade 0	Grade 1	Grade 2	Grade 3
Miyazaki tongue coating index				
T1	17	30	5	3
T2	5	34	13	3
T3	3	27	19	6
Organoleptc measurement *(1-2-3-method)*				
T1	36	17	2	0
T2	18	33	4	0
T3	9	34	10	2
Silness and Löe plaque index				
T1	40	14	1	0
T2	17	30	8	0
T3	9	38	7	1

the simplified index. Although organoleptic measurements are easily performed, studies showed that they often cannot be reproduced. Perception of smell can be influenced by examiner halitosis, affected smell capabilities (e.g. by colds), posture while smelling, and expectation of the examiner (Seemann 2000). However, it can be assumed that experienced and trained examiners deliver largely reproducible results. Women seem to be able to deliver more reproducible results than men (Rosenberg et al. 1991b, Greenman et al. 2004).

In a test study, the investigation was supplemented with halimeter measurements. Due to various factors, and after a through decision-making process, this study refrained from using additional measurements with a halimeter, as the goal was to affect the work of the practitioner as little as possible. The study subjects were also less affected. The literature lists various values with respect to limit and norm. Additionally, the apparatus only measures the sum of volatile sulfur compounds, whereas breath includes other odor-influencing components (e.g. cadaverine, putrescine, indole, skatole) (Jecke 2002).

The results of the subjective evaluations showed no statistically significant difference with respect to the parameters taste, dry mouth and breath odor. There is however a noticeable number of positive values for these parameters, ranging from just under a quarter to a good third of the total. No statistically significant difference was found regarding the frequency of brushing teeth. Most subjects brushed teeth *twice and two to three times* or even *three times or more than three times* per day. It has to be stressed that the orthodontist only provides fixed orthodontic appliances in the case of adequate oral hygiene. When asked after their confidence regarding oral hygiene, however, it became clear that patients struggled to keep up an adequate standard. A statistically significant difference between the three time points ($p=0.003$) illustrated this fact. At T1, a large portion of participants (44/55) indicated to feel *confident* with brushing teeth, whereas this value decreased over the course of the study. When comparing the individual

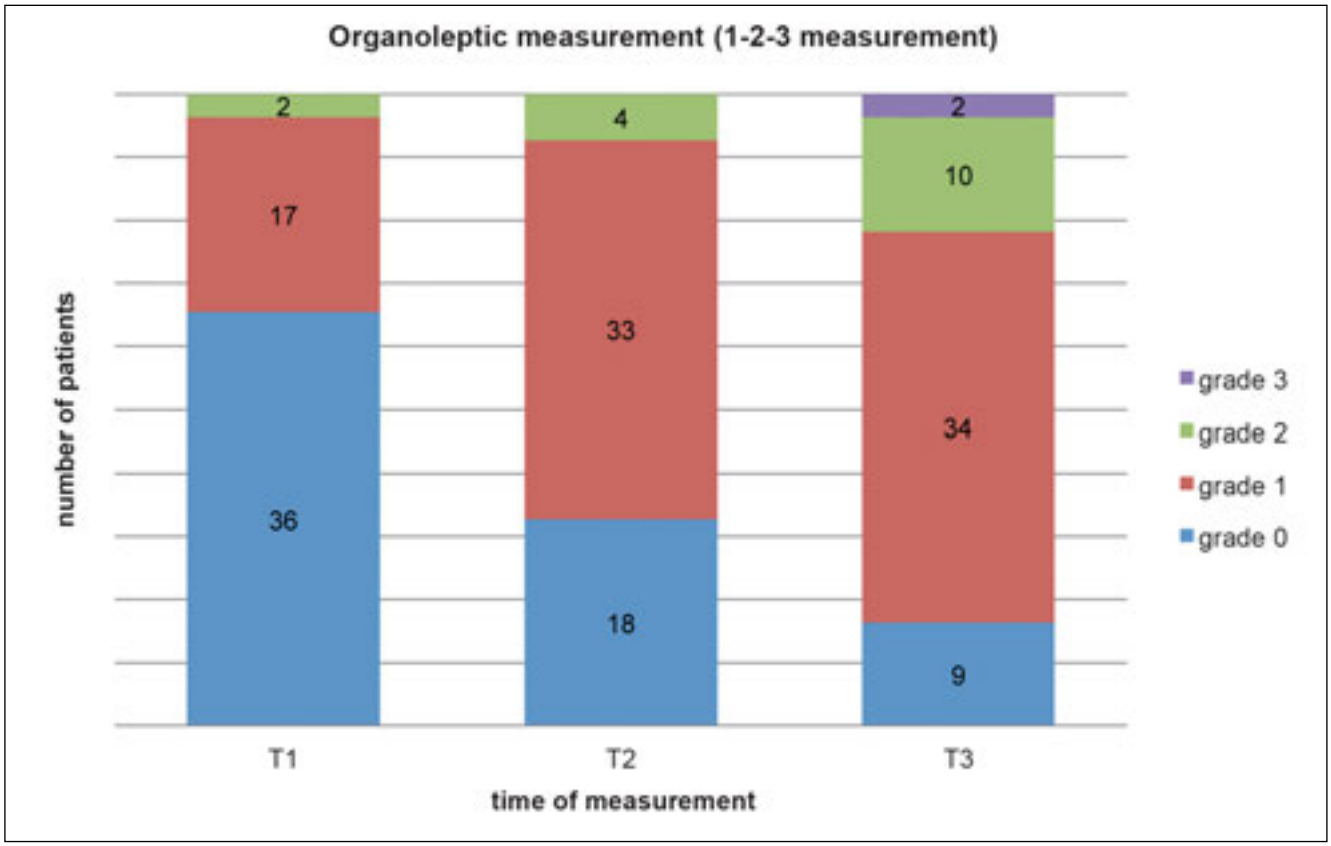

Fig. 2 Results regarding organoleptic measurements performed at three times (T1: immediately after application, T2: 4 weeks after application, T3: 3 months after application)

evaluation regarding oral hygiene with results of the plaque index, they can be found to correlate. Whereas no plaque was generally found at T1 (40/55), this value increased towards grade 1 over the course of the study. It seems it was difficult to perform adequate oral hygiene despite careful instruction. The areas around brackets and wires are mechanically difficult to clean and constitute the main cause for increased plaque accumulation and signs of infection (Alexander 1991). A study by Ristic et al. (2008) describes the effect of fixed orthodontic appliances on subgingival microflora at various times, and finds that probing depth and number of microorganisms increased throughout the first three months after application. After three months, a decrease in both parameters was found. Naranjo et al. (2006) record an increase in plaque, gingival, and bleeding indices, as well as the appearance of periodontally pathogenetic germs. They do not note an influence on probing depth and attachment level. The authors agree that orthodontic treatment encourages plaque accumulation, which can only be counteracted by high dedication to adequate oral hygiene.

The apparent positive correlation with tongue coating is also of interest. A statistically significant difference can be found between T1 and T2 as well as T1 and T3. This result could be explained by the assumption that patients were instructed in dental hygiene but not in the cleaning of the tongue, while at the same time it must be stated that the application of fixed orthodontic appliances obviously has an influence on the manner of coating of the tongue. Similar results were found for organoleptic measurements. Again, statistically significant differences were found between T1 and T2 as well as T1 and T3.

Around 60% of all oral microorganisms are situated on the tongue (Gilmore & Bashkar 1972, Jacobson et al. 1973, Gilmore et al. 1973, Yaegaki & Sanada 1992, De Boever & Loesche 1995), which can be considered the main cause of mouth odor. Studies from recent years establish the relationship between tongue coating and halitosis (Bosy et al. 1994, De Boever & Loesche 1996, Miyazaki et al. 1996, Yaegaki 1997). Orthodontic treatment involving fixed appliances favors the accumulation of plaque, often in connection with gingivitis (Boyd & Baumrind 1992, Davies et al. 1991). Recent studies show a positive correlation between insufficient oral hygiene and the occurrence of breath odor (Maita 1996, Seemann et al. 2001). However, not all patients with insufficient oral hygiene exhibit halitosis. In addition to increased mechanical difficulties when performing dental hygiene, the number and kind of bacteria are considered co-factors for the development of halitosis (Seemann 2000).

In the present study, a statistically significant increase on the plaque and tongue coating indices was observed over the course of the investigation, as well as statistically significantly increased values in organoleptic measurements. A positive correlation between fixed orthodontic appliances and the occurrence of halitosis was established. However, it remains to be seen how the parameters under investigation were to behave in a larger study of more participants and a longer period of monitoring. It is entirely possible for oral hygiene to improve with time and that the factors determining the ecosystem of the oral cavity were subsequently modified.

The occurrence of halitosis during orthodontic treatment involving fixed orthodontic appliances is an indicator of oral health for practitioners. Organoleptic measurements can easily be performed during conversation with the patient and during clinical consultation. Because of the socially and professionally inhibiting nature of halitosis, this study's results are relevant insofar as they might serve as motivating factors for patients to dedicate themselves to maintaining adequate oral hygiene.

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Résumé

L'halitose est très répandue dans la population. Les causes peuvent être multiples. Le but de cette étude était de déterminer si les appareils orthodontiques fixes favorisent l'halitose.

55 patients d'un cabinet d'orthodontie ont été examinés à trois intervalles de temps (T1: avant l'insertion de l'appareil orthodontique, T2: 4 semaines après l'insertion, T3: 3 mois après l'insertion).

L'index de plaque, l'index de dépôt sur la langue, une évaluation organoleptique et une autoévaluation des patients ont été enregistrés. Aucune différence signifiante entre les paramètres subjectifs comme saveur, sécheresse orale et halitose ont été visibles. Néanmoins, les appareils orthodontiques ont entravé l'hygiène orale ($p=0,003$). Des différences signifiantes concernant l'index de dépôt sur la langue entre T1 et T2 ($p=0,012$) et T1 et T3 ($<0,001$) ont été enregistrées. Les paramètres mesurés pour l'évaluation organoleptique (T1 et T2 [$p=0,002$]; T1 et T3 [$p<0,001$]) et l'index de plaque [(T1 et T2/ T3 ($p<0,001$)] se comportaient de façon identique.

Les appareils orthodontiques fixes causent une progression de l'index de plaque, de l'index de dépôt sur la langue et de l'évaluation organoleptique. La présente étude montre une corrélation positive entre le port d'un appareil fixe d'orthodontie et l'halitose. L'halitose peut être un indicateur pour l'évaluation de la santé orale et peut être utilisée comme instrument de motivation pour acquérir une hygiène dentaire adéquate.

References

Alexander S A: Effects of orthodontic attachments on the gingival health of permanent second molars. Am J Orthod Dentofacial Orthop 100: 337–340 (1991)

Amir E, Shimonov R, Rosenberg M: Halitosis in children. J Pediatr 134: 338–343 (1999)

Babacan H, Sokucu O, Marakoglu I, Ozedmir H, Nalcaci R: Effect of fixed appliances on oral malodor. Am J Orthod Dentofacial Orthop 139: 351–355 (2011)

Benson P E, Pender N, Higham S M: Quantifying enamel demineralization from teeth with orthodontic brackets – a comparison of two methods. Part 2: validity. Eur J Orthod 25: 159–165 (2003)

Benson P E, Shah A A, Willmot D R: Measurement of white lesions surrounding orthodontic brackets: captured slides vs digital camera images. Angle Orthod 75: 226–230 (2005)

Bornstein M M, Kislig K, Hoti B B, Seemann R, Lussi A: Prevalence of halitosis in the population of the city of Bern, Switzerland: A study comparing self-reported and clinical data. Eur J Oral Sci 117: 261–267 (2009)

Bosy A, Kulkarni G V, Rosenberg M, McCulloch C A: Relationship of oral malodor to periodontitis: evidence of independence in discrete subpopulations. J Periodontol 65: 37–46 (1994)

Boyd R L, Baumrind S: Periodontal considerations in the use of bonds and bands on molars in adolescents and adults. Angle Orthod 62: 117–126 (1992)

Davies T M, Shaw W C, Warthington H V, Addy M, Dummer P, Kingdon A: The effect of orthodontic treatment on plaque and gingivitis. Am J Orthod Dentofacial Orthop 99: 155–161 (1991)

De Boever E H, Loesche W J: Assessing the contribution of anaerobic microflora of the tongue to oral malodor. J Am Dent Assoc 126: 1384–1393 (1995)

De Boever E H, Loesche W J: The tongue microbiota and tongue surface characteristics contribute to oral malodour. In: Van Steenberghe D, Rosenberg M (Hrsg.): Bad breath. A multidisciplinary approach. University Press, Leuven, pp 111–123 (1996)

Delanghe G, Ghyselen J, Feenstra L, van Steenberghe D: Experiences of a Belgian multidisciplinary breath odour clinic. In: Van Steenberghe D, Rosenberg M (Hrsg): Bad breath. A multidisciplinary approach. Ramot Leuven, pp 199–209 (1996)

Delanghe G, Ghyselen J, Van Steenberghe D, Feenstra L: Multidisciplinary breath-odour clinic. Lancet 350: 187–188 (1997)

Delanghe G, Ghyselen J, Bollen C, Van Steenberghe D, Vandkerckhove B N A, Feenstra L: An inventory of patients' response to treatment at a multidisciplinary breath odor clinic. Quintessence Int 30: 307–310 (1999)

Ellis P E, Benson P E: Potential hazards of orthodontic treatment – what your patient should know. Dental Update 29: 492–496 (2002)

Forsberg C M, Brattström V, Malmberg E, Nord C E: Ligature wires and elastomeric rings: two methods of ligation, and their association with microbial colonization of Streptococcus mutans and lactobacilli. Eur J Orthod 13: 416–420 (1991)

Gilmore E L, Bhaskar S N: Effect of tongue brushing on bacteria and plaque formed in vitro. J Periodontol 43: 418–422 (1972)

Gilmore E L, Gross A, Whitley R: Effect of tongue brushing on plaque bacteria. Oral Surg Oral Med Oral Pathol 36: 201–204 (1973)

Glasspoole E A, Erickson R L, Davidson C L: Demineralization of enamel in relation to the fluoride release of materials. Am J Dent 14: 8–12 (2001)

Greenman J, Duffield J, Spencer P, Rosenberg M, Corry D, Saad S, Lenton P, Majerus G, Nachnani S, El-Maaytah M: Study on the organoleptic intensity scale for measuring oral malodor. J Dent Res 83: 81–85 (2004)

Gwinnett A J, Ceen R F: Plaque distribution on bonded brackets: a scanning microscope study. Am J Orthod 75: 667–677 (1979)

Hughes F J, McNab R: Oral malodour – a review. Arch Oral Biol 53 (Suppl. 1): 1–7 (2008)

Jacobson S E, Crawford J J, Mc Fall W R: Oral physiotherapy of the tongue and palate: relationship to plaque control. J Am Dent Assoc 87: 134–139 (1973)

Jecke U: Klinische Studie zur Beurteilung oraler Risikoparameter für Halitosis. Med. Diss. München (2002)

Lang B, Filippi A: Halitosis – Teil 1: Epidemiologie und Entstehung. Schweiz Monatsschr Zahnmed 10: 1037–1044 (2004)

Lee S M, Yoo S Y, Kim H S, Kim K W, Yoon Y J, Lim S H, Shin H Y, Kook J K: Prevalence of putative periodontopathogens in subgingival dental plaques from gingivitis lesions in Korean orthodontic patients. J Microbiol 43: 260–265 (2005)

Loesche W J, Grossmann N, Dominguez L, Schork M A: Oral malodour in the elderly. In: Van Steenberghe D, Rosenberg M (Hrsg): Bad breath. A multidisciplinary approach. Ramot Leuven, pp 181–195 (1996)

Maita E: A simple detector for oral malodour. In: Van Steenberghe D, Rosenberg M (Hrsg): Bad breath. A multidisciplinary approach. Ramot Leuven, pp 209–217 (1996)

Mitchell L: Decalcification during orthodontic treatment with fixed appliances – an overview. Br J Orthod 19: 199–205 (1992)

Miyazaki H, Sakao S, Katoh Y, Takehara T: Correlation between volatile sulphur compounds and certain oral health measurements in the general population. J Peridontol 66: 679–684 (1995)

Miyazaki H, Fujita C, Katoh Y, Takehara T: Relationship between volatile sulphur compounds and oral conditions in the general Japanese population. In: Van Steenberghe D, Rosenberg M (Hrsg): Bad breath. A multidisciplinary approach. Ramot Leuven, pp 165–181 (1996)

Naranjo A A, Trivino M L, Jaramillo A, Betancourth M, Botero J E: Changes in the subgingival microbiota and periodontal parameters before and 3 month after bracket placement. Am J Orthod Dentofacial Orthop 275: 17–22 (2006)

Persson S, Edlund M B, Claesson R, Carlsson J: The formation of hydrogen sulfide and methyl mercaptan by oral bacteria. Oral Microbiol Immunol 5: 195–201 (1990)

Preti G, Clark L, Cowart B J, Feldman R S, Lowry L D, Weber E, Young I M: Non-oral etiologies of oral malodor and altered chemosensation. J Periodontol 63: 790–796 (1992)

Ristic M, Vlahovic Svabic M, Sasic M, Zelic O: Effects of fixed orthodontic appliances on subgingival microflora. Int J Dent Hygiene 6: 129–136 (2008)

Rosenberg M, Septon I, Eli I, Bar-Ness R, Gelernter I, Brenner S, Gabbay J: Halitosis measurement by an industrial sulphide monitor. J Periodontol 62: 487–489 (1991A)

Rosenberg M, Kulkarni G V, Bosy A, McCulloch C A: Reproducibility and sensitivity of oral malodor measurements with a portable sulphide monitor. J Dent Res 70: 1436–1440 (1991B)

Rosenberg M, McCulloch C A: Measurement of oral malodor: current methods and future prospects. J Periodontol 63: 776–782 (1992)

Rosenberg M, Leib E: Experiences of an Israeli malodor clinic. In: Rosenberg M (Hrsg): Bad breath. Research perspectives. Ramot, Tel Aviv, pp 137–148 (1997)

Seemann R: Wenn der Atem stinkt. Zahnärztl Mitt: 90: 502–505 und 644–648 (2000)

Seemann, R: Halitosis – ein lösbares Problem. Zahnärztlicher Anzeiger München 47: 4–7 (2001)

Seemann R, Passek G, Zimmer S, Roulet J F: The effect of an oral hygiene program on oral levels of volatile sulfur compounds (VSC). J Clin Dent 12: 104–107 (2001)

Sharma N C, Galustians H J, Qaquish J: The clinical effectiveness of a dentifrice containing triclosan and a copolymer for controlling breath odor measured organoleptically twelve hours after toothbrushing. J Clin Dent 10: 131–134 (1999)

Silness P, Löe H: Periodontal disease in pregnancy II. Correlation between oral hygiene and periodontal condition. Acta Odontol Scand 22: 121–135 (1964)

Svanberg M, Ljunglöf S, Thilander B: Streptococcus mutans and Streptococcus sanguis in plaque from orthodontic bands and brackets. Eur J Orthod 6: 132–136 (1984)

Van den Broek A M W T, Feenstra L, De Baat C A: A review of the current literature on aetiology and measurement methods of halitosis. J Dent 35: 627–635 (2007)

Van Steenberghe D, Avontroodt P, Peeters W, Pauwels M, Coucke W, Lijnen A, Quirynen M: Effect of different mouthrinses on morning breath. J Periodontol 72: 1183–1191 (2001)

Waler S M: On the transformation of sulfur-containing amino acids and peptides to volatile sulfur compounds (VSC) in the human mouth. Eur J Oral Sci 105: 534–537 (1997)

Yaegaki K: Oral malodor and periodontal disease. In: Rosenberg M (Hrsg): Bad breath. Research perspectives. Ramot, Tel Aviv, pp 87–108 (1997)

Yaegaki K, Coil J M: Examination, classification, and treatment of halitosis – clinical perspectives. J Can Dent Assoc 66: 257–267 (2000)

Yaegaki K, Sanada K: Volatile sulfur compounds in mouth air from clinically healthy subjects and patients with periodontal disease. J Periodontal Res 27: 233–238 (1992)