The Influence of a Season on Bond Failure Rate of Metal Orthodontic Brackets: A Prospective Clinical Study

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Running head: Seasons and bond failures

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ABSTRACT

Objective: The aim of the study was to determine the influence of a season on bond failures of metal brackets using a modified method of direct bonding over a period of 12 months.

Methods: The clinical study involved thirty patients, 8 men and 22 women, who had a total of 600 metal orthodontic brackets 022" (Mini Sprint®, Forestadent, Germany) placed. Transbond XT™ (Transbond XT™ Paste and Primer, 3M, Monrovia, CA, USA) adhesive material was applied. All brackets and tubes were placed using a modified direct bonding method. Bond failures were monitored within 12 months from the initial bonding.

Results: The results showed that out of the total number of the placed brackets, 10 (1.67%) brackets fell off. The highest number of bond failures, 3 (3%) cases, occurred if they were placed in February and March, respectively, while 4 (3.33%) cases of debonding occurred in October. In the period from May to September, as well as in January and November, there was no bond failures.

Conclusion: The results showed a difference in the number of bond failures depending on the season, where the largest number of failed brackets was in the winter period, i.e. in October and December.

Keywords: direct bonding, seasons, bond failures, metal brackets, light cure adhesives

INTRODUCTION

The strength of the bond between the bases of the brackets and the tooth enamel is a significant parameter in the course of a several-month orthodontic therapy with fixed appliances. Bond failures during the therapy lead to a series of unpleasant and frustrating situations. Re-bonding of failed brackets is a complex and unpleasant procedure, which has its negative repercussions in the daily and fixed schedule of patients, prolongation of the total therapy time, mechanical injuries to soft intraoral tissues, standing for an economically unprofitable repeated procedure (Ribeiro et al, 2016; Almosa et al, 2018).

Seasons and their association with bond failures during initial bonding, as well as the time period of the therapy with fixed orthodontic appliances, can exert their influence over two parameters - temperature and humidity. As the temperatures of the external environment are inversely proportional to the temperatures in the rooms, we have to include their repercussions on the humidity, especially when rooms are heated in the winter and cooled in the summer, and on the material used for bonding the brackets, especially on the primers. When talking about humidity, other parameters that can affect the bonding process should be taken into account: the number of people in one office, size of the room, ventilation, etc. Studies on this topic warn that temperature differences, as well as the intensity of the city's heat, lead to an increase in air humidity, which has an impact on people's behavior and their heat load, physiological functioning and performance of daily tasks (Vargas et al, 2020; Vecellio et al, 2022; Havenith et al, 2015).

Selection of adhesive material and brackets, manual work, choice of bonding procedure, patient’s behavior and ortodontist’s concentration are just some of the factors that can be important for successful bonding (Bai et al, 2023; Czolgosz et al, 2021; Wang et al. 2022; Scribante et al, 2022; Akl et al, 2022; Tan et al, 2022).

When it comes to the seasons, there are two parameters that can have an impact on bond failures: temperature and air humidity. Global warming of the planet has inevitably led to higher temperature values. Temperature differences will be certainly increased with climate changes, as it is predicted that heat waves will increase in frequency, intensity and duration (Seneviratne et al,2021). The warming of the atmosphere inevitably leads to higher evaporation, and thus to higher humidity on the global level. Also, humidity depends on the number of people in the office, its size and ventilation, and it represents one of the key factors that could have an effect on the material used, and thus be important in the direct bonding procedure. As the outside temperatures are higher, cooling of the interior rooms is necessary and vice versa. Heat represents the most direct way in which climate change affects people's health and their work efficiency. Solving cross-disciplinary challenges is necessary to ensure better human health and smooth work process (Baldwin et al, 2023).

A modified method of direct bonding that was used differs from the conventional one in the application phase, in which the tooth surface of the demineralized areas is left dry, while the primer is applied to the adhesive over the bracket bases.

The aim of the study was to determine the differences in the number of failed brackets in relation to the seasons when they were placed, regardless of patient's age, gender and type of malocclusion within a period of 12 months from the initial bonding, using the modified direct method.

HYPOTHESIS. There is no difference in the number of failed brackets bonded with modified direct method in relation to the season when the initial bonding was performed in patients regardless of their age, gender and type of malocclusion, for a period of 12 months.

MATERIALS AND METHODS

The prospective clinical study was performed at the Clinic for Dental Medicine in Nis, Serbia and approved by the Ethics Committee of the Clinic for Dental Medicine (under number: 14/7-2019-4 EO; 18.01.2022).

A complete collected dental administrative documentation of all patients in the study was performed at the Clinic for Dental Medicine in Nis, at the Department of Orthopedics of Jaws and Teeth, in the period from December 2019 to January 2023. The patients accepted their participation in the study verbally, and confirmed their consent in writing. Parents/guardians signed the written consents for their minors. The clinic for dental medicine belongs to the tertiary level of healthcare. In terms of dental interventions, it is one of the leaders in the region, to which a significant number of patients from Nis, the surrounding smaller towns and larger cities gravitate.

The inclusion factors for the selection of patients in the study were: patients with full dental arch and without previous orthodontic treatment with fixed appliances, patients in whom tooth extraction was not necessary, patients in whom orthodontic therapy with fixed orthodontic appliances with full arches was indicated, those without composite fillings on the buccal surfaces of the teeth and without prosthetic restorations, patients without syndromes, and those who understood the importance of the oral hygiene maintenance. The exclusion factors were patients with incomplete dental arches, prosthetic restoration on the buccal surfaces of the teeth, inadequate oral hygiene, patients in whom extraction therapy was indicated, those who were in the process of preparation for orthognathic surgery, as well as patients with special needs.

A total of 30 patients (mean age 17.07±5.35), of which 8 males (mean age 18.77±7.87) and 22 females (mean age 16.45±4.17) participated in the study, and a total of 600 brackets with Roth bracket prescription 0.022" were placed (Mini Sprint®, Forestadent, Germany). Tubes on the molars were not included in the study. Straight-wire appliance (SWA) technique was used in therapy of selected patients, without the application of mobile and functional orthodontic appliances. Dental prophylaxis of all patients in the study was performed at least one week before the initial bonding of the brackets, and was not part of the modified method of direct bonding, which tested the discipline and motivation of the patients who met the study criteria.

The modified method of direct orthodontic bonding included the following steps: drying of the teeth and isolation of the working field using a water roller only in the area of the vestibule at the angles in the lower jaw under the canines, while the patient made contact with the incisal edges of the upper incisors with a suction cup. Acid-etching with 37% orthophosphoric acid gel (Etching Gel, 3M, Monrovia, CA, USA) was performed in duration of 20 seconds on the corresponding buccal surfaces of the teeth, slightly larger than the bracket bases. The acid was removed from the teeth by rotating the water-moistened end of the water bottle, then with a brush under a stream of water from the immediate vicinity. The remains of acid and waste products were washed away, with a later replacement and application of dry water bottles in the vestibule of the canine area, while drying the teeth under slight air pressure from the brush away from the teeth. Primer (Transbond XT™ Primer, 3M, Monrovia, CA, USA) was applied to the bracket base using a microapplicator (Disposable Micro Applicators, Med Comfort, Ampri GmbH, Germany); then, adhesive (Transbond XT™ Paste, 3M, Monrovia, CA, USA) was applied over the primer on the bracket base, and finally the primer was re-applied over the adhesive, with a light pressure. The surface of the previously conditioned buccal areas of the teeth was kept dry. The brackets prepared in this way were positioned, placed and slight pressure was applied in the vertical slot of the frontal part of the brackets using a dental pick. Excess adhesive material around the base of the brackets was removed with a sharp probe. Polymerization was performed for 20 s after the brackets were placed using a LED lamp - Woodpecker Dental Curing Light (LED B. Curing Light, Guangxi, China).

The sequence of bracket bonding was as follows: after the tubes were placed on all four first permanent molars, the brackets were bonded first from the second lower premolar to the canine on the right and in the same order on the left side, and then they were placed in the frontal region of the lower jaw. The same sequence of brackets was in the upper jaw. After the last bracket was placed, a 15-minute pause was made to place the initial .014" NiTi archwires (G & H Wire Co., Indiana, USA) first on the lower and then on the upper arch. Later in the course of therapy, archwires of stainless steel, .016”, .018” (G & H Wire Co., Indiana, USA) and then square arches .016x.016, .016x.022, .018x.025” and .019x.025” (G & H Wire Co., Indiana, USA) were placed. Arches were replaced per eight weeks. In patients with the distal and mesial position of the mandible, orthodontic class II and III elastics (4 ½ oz., Size 5/16", 7.9mm Medium, American Orthodontics, USA) were used.

Disarticulators (OptiBand Ultra, Light Cure Band Blue Cement, Glendora, CA 91740, USA) were placed on the occlusal surfaces of the lower first permanent molars in those patients in whom antagonist contact with the brackets of the opposite jaw was performed.

All brackets were placed by the first author (VM) with 18 years of work experience, while the replacement of orthodontic arches and ligation of brackets was performed by the second author (AT). This improved objectivity in the paper, with the second author being blinded to the type of direct bonding method.

After bonding, patients were advised not to consume solid food in the next 48 hours, to avoid consumption of chewing gums, gummy candies, and popcorns in the following 48 hours, and not to bite off pieces of food. They were also instructed how to maintain oral hygiene and how to brush their teeth. Patients were monitored for a period of 12 months. Patients were required to report any bond failure during the mentioned period. All bond failures were treated in the same way as in the initial bonding, however, with previous removal of excess adhesive using carbide burs (RA US5, Medin, Novo Mesto, Czech Republic) on the Dental Set 400 working unit (Dental Chair SYNCRUS G2, Water Unit SYNCRUS G2, Delivery Unit SYNCRUS G3 H, Dental Light SIRIUS G8 SENSOR, Alliage, Brasil).

STATISTICAL analysis. The number of bond failures is shown as a proportion of bonded brackets in relation to the total number of placed brackets, where differences in the number of bond failures in relation to months were tested with the Chi-square test. The time to bond failure and survival time of brackets were described by the arithmetic mean and standard deviation, while the differences in the average time of bond failures and duration of brackets were tested by t-test and F-test.

Statistical analysis (Student's t-test and chi-square test) determined a significance level of 0.05. The analysis was performed in the program IBM SPSS ver. 22, G*Power, version 3.1.9.4. Author Franz Faul, University of Kiel, Germany.

RESULTS

In the period from December 2019 to January 2023, a total of 600 brackets were placed in 30 patients who took part in the study. Out of the total number of bonded brackets, a total of 10 bond failures (1.67%) occurred. The average time to bond failure was 5.4 months ± 2.41. The shortest time to bond failures was two months and the longest was ten months (Table 1).

Table 1. Time to first bond failures

	N	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**
Number of months to debonding	10	2.0	10.0	5.400	2.4129

On average, 60 brackets were placed every month except in April and June. An exact overview of the number of placed brackets per month is presented in Table 2.

Table 2. Number of bonded brackets per month

Month	Frequency	Percent	Cumulative percent
January	40	6.7	6.7
February	20	3.3	10.0
March	80	13.3	23.3
May	60	10.0	33.3
July	20	3.3	36.7
August	20	3.3	40.0
September	100	16.7	56.7
October	120	20.0	76.7
November	40	6.7	83.3
December	100	16.7	100.0
Total	600	100.0	

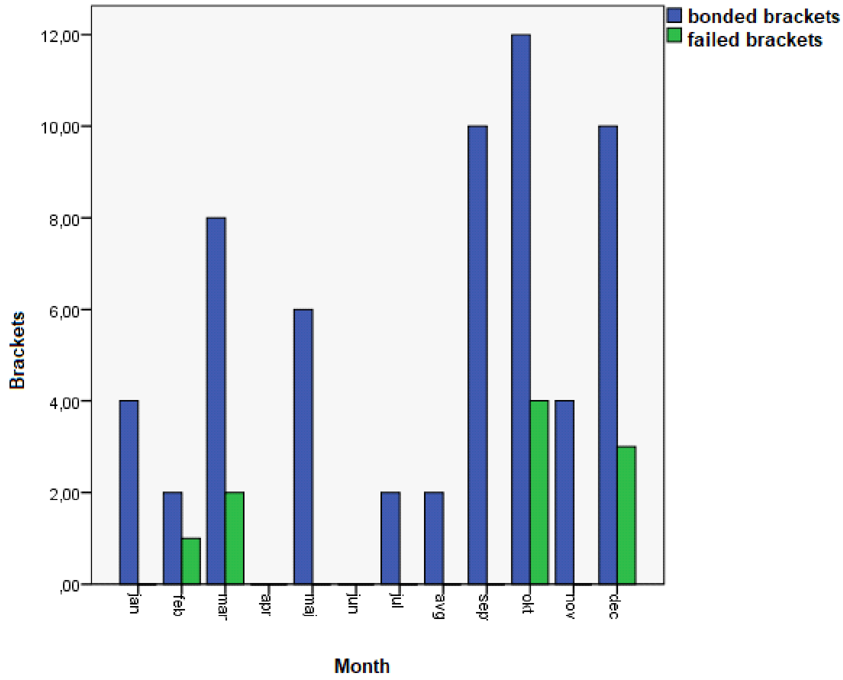
The results of differences in the number of bond failures bonded in different months are shown in Table 3.

Table 3. The number of bonded brackets and bond failures according to the month in which brackets were placed

The placement month	Bonded brackets (number)	Bond failures (number)	Bond failures percent	Average time to bond failure in months
January	40	0	0	-
February	20	1	5	8
March	80	2	2.5	8.5
May	60	0	0	-
July	20	0	0	-
August	20	0	0	-
September	100	0	0	-
October	120	4	3.33	4.25
November	40	0	0	-
December	100	3	3	4
Total	600	10	1.67	5.4

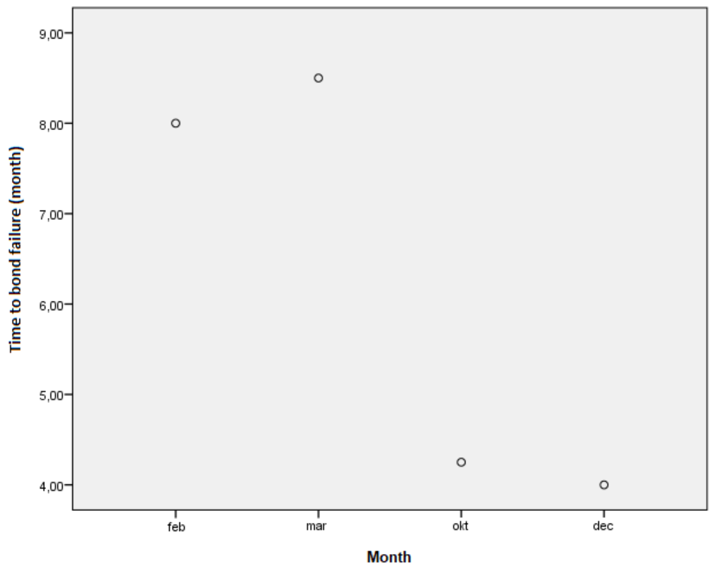
In February and March, 100 brackets were placed, with 3 bond failures (3%); in December, 100 brackets were placed with 3 bond failures (3%), while in October, 120 brackets were placed and 4 fell off (3.33%). In all other months, 280 brackets (46.7%) were placed and there were no bond failures after 12 months. As for the brackets placed from May to September (200 brackets), as well as the brackets placed in January (40) and November (40), there were no bond failures.

Graph 1. The number of bonded and failed brackets per month



The earliest bond failures were reported for the brackets bonded in December and October, and the latest in those placed in February and March. The differences in the number of months until bond failures were statistically significant [$F(3.6) = 4.872$; $p=0.048$].

Graph 2. Time to bond failures according to the month of bracket placement



If the results are analyzed by the month when bond failures occurred, it can be seen that bond failures were very uniform (Table 4).

Table 4. Frequency of bond failures according to the month of bracket placement

Placement month	Frequency*	Percent (%)
January	2	20
February	2	20
March	2	20
April	1	10
June	1	10
October	2	20
Total	10	100

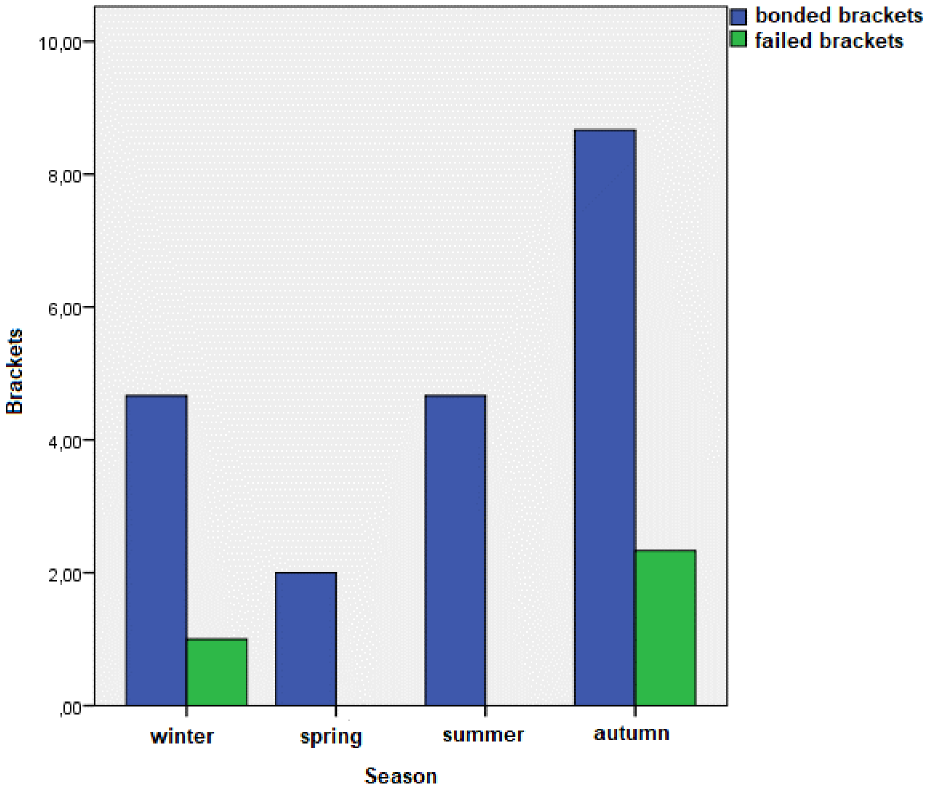
*number of bond failures

As for the brackets placed in the period between October and March (400), there were 10 (2.5%) bond failures, while there were no bond failures at all among the brackets bonded in spring or summer (200 brackets) (Table 5).

Table 5. Bond failures according to the season in which the brackets were placed

Season	Placed	Bond failures	Percent (%)
spring	60	0	0
summer	140	0	0
autumn	260	7	70
winter	140	3	30
Total	600	10	100

Graph 3. The number of bonded brackets and bond failures per season in which the brackets were bonded



As for the time of year when bond failures occurred, the most often were in winter, and very rarely in spring and summer (Table 6).

Table 6. Bond failures according to the season in which the brackets were placed

Season	Placed	Bond Failures	Percent (%)
spring	60	1	10
summer	140	1	10
autumn	260	2	20
winter	140	6	60
Total	600	10	100

The chi-square statistic is 7.9121. The p-value is 0.047864. The result is significant at $p < 0.05$.

For 30 patients and 600 brackets placed, the total number of bond failures was 10 (1.67%). Looking at the time of year, the largest number of failed brackets occurred in autumn (70%), while the largest number of bond failures compared to the placed ones was when the initial bonding was in the winter period (60%). There were no bond failures when the brackets were placed in spring and summer, while only one bracket fell off during these two seasons when they were placed, and 10 (2.5%) brackets fell off in the period from October to March, out of the total of 400 brackets placed in that period.

DISCUSSION

The study represents a prospective clinical investigation of bond failures within 12 months from the initial bonding with a modified direct method, so the comparison of the obtained results was made in relation to the available data from the literature concerning the conventional method of direct bonding. Based on the presented results, the null hypothesis was rejected and the statement that there was a difference in the number of bond failures with reference to the seasons of initial bonding using the modified direct method was accepted.

When it comes to the number of bond failures in the available literature (Roelofs et al, 2017; Ogiński et al, 2020; Vasudaven et al, 2020), using the conventional method of direct bonding, the percentage ranges from 1.8-15.42%. In relation to the mentioned values of bond failures, the results in our study are in agreement with the described results.

In addition to the impact on people, the seasons also have an impact on dental materials through temperature. Transbond XT is an adhesive material that represents one of the more viscous dental materials. The viscosity of any adhesive material is estimated based on the type and amount of monomers in them. Bean et al. (Beun et al, 2008; Beun et al, 2009) indicated that the type of monomer in the composition of adhesive materials is directly related to the viscosity of the organic matrix of the material. The interaction of monomer molecules is correlated with viscosity values, which in general demonstrates that larger monomer molecules will have higher viscosity values, while materials with smaller monomer molecules will have lower viscosity values. Transbond XT contains a large molecule Bis-GMA (bisphenol A diglycidyl ether dimethacrylate) and TEGDMA (triethylene glycol dimethacrylate), where the Bis-GMA exhibits a higher degree of viscosity at room temperature, noting that such material will be more difficult to manipulate during procedure. Therefore, Bis-GMA would have to be dissolved with lower values of more viscous esters such as TEGDMA in order to reduce the viscosity. At elevated temperatures (25°C to 35°C), adhesive materials, including primers, become less viscous (Abdul Aziz et al, 2015). The amount of fillers, the size of monomers, their proper dispersion in the composition of fluid polymers before hardening is of vital importance in the manifestation of the mechanical characteristics of dental materials. Transbond XT has excellent diametral tensile strength, adequate flexural strength, slightly weaker compressive properties and a low modulus of elasticity. The stiffness of this adhesive material can affect the behavior of an adequate bond with tooth enamel during long-term orthodontic therapy (Ghoubril et al, 2020). Sho Goto et al. (Goto et al, 2020) indicated that orthodontic adhesive materials with a higher degree of viscosity and a large amount of filler give a stronger bond between the two adherents. A more homogenized adhesive material is justified in order to achieve an appropriate

distribution of components in it and thereby obtain adequate fluidity (Ogliari et al, 2007), which improves penetration and reduces the thickness of the adhesive between the adherents during bonding (Mohammadi et al, 2018), but also facilitates the operator's manual work. Manufacturers recommend that dental materials are stored at room temperature, while the same materials are stored in the refrigerator in the summer months when the ambient temperature is higher in order to cool them and extend their expiration date. In clinical practice during the summer months, clinicians use material from the refrigerator without waiting for the material to reach room temperature. Such low temperatures achieved by cooling in the refrigerator can have a negative impact on the physical-mechanical characteristics of the material, on inadequate polymerization, which will result in a decreased efficiency in manual work with dental materials (Akarsu et al, 2019). The coefficient of thermal expansion of brackets and adhesives leads to the circular stress of contraction and expansion of the material (González-Serranoet al. 2019). The higher the coefficient of thermal expansion of the adhesive material, the weaker the adhesive bond will be, because the volume changes in the material will be greater (Farella et al, 2016). Roelofs (Roelofs et al, 2017) emphasizes that the technical challenges of the dental chair, the lights on the work unit or the pad can be important in obtaining a smaller number of bond failures, that is, factors that could affect obtaining an adequate connection between adherents. A novel approach of direct bonding avoids mentioning technical defects, whereby premature incomplete polymerization of the primer by the light from the work unit is not allowed. The adhesive material for modified bonding prepared in this way is exposed to short-term effects of moisture from humid air through breathing of patients, as well as from room humidity that is related to temperature values and the presence of a large number of people in the office. In this way, more optimal conditions are enabled in order to overcome the technical challenges and shortcomings of direct bonding during different periods of a year in relation to the temperature characteristics that each season brings.
Frequent temperature differences of food and drinks with reference to different months when they are consumed cause sudden temperature changes in the oral cavity. Weather these changes affect bond failures and whether they have an effect on the adhesive bond between the adherents should be further investigated, according to which orthodontic recommendations could be revised (Kuśmierczyk et al, 2019). Eating habits of patients with fixed orthodontic appliances that cause sudden temperature changes in the oral cavity can play a significant role in adequate adhesion. It is important to mention that the temperatures measured on the surface of the teeth, excluding periods of food and drink consumption, show mean values that are lower than what is usually assumed for the temperature of the oral cavity, which is generally assumed to be around 37 °C. This phenomenon is caused by air flow during breathing and speaking, ambient temperature, the degree of lip closure (lip incompetence), the way of breathing and individual characteristics that have an impact on body temperature, such as hormonal fluctuations during the day, the health status of patients, age, use of medicines, etc. The temperature range and the time of oral exposure to extreme temperature fluctuations are individual for each patient, which largely depends on the

nutritional habits of individuals, their tolerance to the temperatures of meals and drinks, as well as the way they are consumed (Palesik et al, 2022). Our study showed that bonding during spring and summer did not lead to subsequent bond failures, which can be explained by lower temperatures in the rooms due to cooling and higher external temperatures. By direct combining of low-viscosity primer and a more consistent adhesive paste, faster homogenization of the material is enabled, as well as easier manual work and application of the material during the initial bonding in the mentioned seasons. With this approach in direct bonding, a better penetration of the material in the adherents is possible, which is reflected in the easier fluidity of the adhesive, especially during the winter months, but also if the material was previously stored in the refrigerator.
It is noted that the issue of temperature can be viewed from several aspects. External temperature, room temperatures, patients' oral cavity temperatures, food consumed by patients, the effect of heat and cold on dental materials, the physiology of orofacial functions of patients, the geographical location in which they live and work, humidity are just some of the parameters that could affect the adhesive characteristics of materials used in bonding brackets.
The mentioned positive effects and qualitative characteristics of the modified method of direct bonding represent very important parameters in higher quality manual work, the advantages of which can have an impact on the satisfaction of orthodontists on a global level, as well as the satisfaction of patients. Simplification of procedures, faster and more efficient work, reduced chair time, more economical and acceptable work handling, with maximum safety of all actors represent the highest level of patient healthcare in order to obtain good results.
We believe that using a modified method of direct bonding, which has its own qualitative advantages compared to the conventional method, can be the procedure of choice when it comes to obtaining quality adhesion in orthodontics.

LIMITATIONS. The study had several limitations. We have not come across any studies in the literature that have linked seasons to bond failures. Also, the period of the pandemic (COVID 19) meant that we had a smaller number of patients. We did not measure the temperature and air humidity in the rooms used for bonding, nor the temperature of the oral cavity of each patient. It is difficult to assess and control the eating and living habits of each individual. Only one adhesive was used. As far as we know, according to data from the literature, this is the first paper on the topic of the association of bond failures with the seasons. The significance of the work is reflected in the presented results, which shows a clinical picture of the relation between the season and bond failures. The modified method of direct bonding was applied, which showed several qualitative characteristics with a certain advantage over conventional bonding.

CONCLUSION

Based on the results of the clinical study, using the modified method of direct bonding, we conclude that:

• there is a difference in the number of bond failures depending on the month of bonding;

• no bond failures were recorded with brackets placed in the period from May to October, as well as those placed in January and November;

• the largest number of bond failures occurred in the winter period, i.e. in October and December.

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