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Bisphenol A release in the saliva of children with Haas expanders

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Objective: Several studies have highlighted the toxic potential of bisphenol A (BPA), however, BPA release from orthopedic devices remains poorly investigated. Therefore, this study aimed to evaluate BPA levels in the saliva of children treated using Haas expanders. **Methods:** Twenty-two children of both sexes aged 6–10 years who required rapid maxillary expansion were recruited. One week after placement of elastics to separate the permanent molars, orthodontic bands were adapted, and maxillary impressions were obtained using alginate impression material. Haas expanders were fabricated using a standardized amount of acrylic resin. The bands were cemented using Transbond Plus Light Cure Band (3M). Saliva samples were collected at five time points: before (T0) and 30 minutes (T1), 24 hours (T2), 1 week (T3), and 1 month (T4) after Haas expander installation. BPA levels were measured using ultra-high-performance liquid chromatography coupled with Tandem Mass Spectrometry. The results were evaluated using one-way analysis of variance with Tukey's post-hoc test (alpha = 5%). **Results:** BPA levels were below the recommended tolerable daily intake (TDI) at all timepoints; however, salivary BPA levels at T1 (70.324 ng/mL ± 37.05) and at T2 (18.015 ng/mL ± 11.22) were significantly higher compared to that at T0 (0.475 ng/mL ± 0.27) ($P < 0.05$). **Conclusions:** Salivary BPA levels significantly increased 30 minutes and 24 hours after Haas expander installation and return to baseline values after 1 week. BPA levels did not exceed the TDI, suggesting that the use of Haas expanders may be considered safe concerning BPA exposure in children.

Key words: Expansion, Adhesive, Appliances, Biocompatibility

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INTRODUCTION

Bisphenol A (2,2'-bis [4-hydroxyphenyl] propane) (BPA) is a synthetic chemical widely used in the production of epoxy resins and polycarbonate plastics. Owing to the increased number of epoxy-based products, human exposure to BPA has rapidly increased.[1-3] BPA is used to manufacture of various products, such as detergents, pesticides, and dental materials such as resins, adhesives, and fissure sealants.[4,5]

Studies have indicated that human exposure to BPA may result in adverse effects, mainly owing to its toxic potential.[6] According to the European Food Safety Authority (EFSA, 2023), the tolerable daily intake (TDI) of BPA is 0.2 ng/kg body weight per day.[6] However, the daily human consumption of this compound may reach 9.9 times the TDI,[7] which might potentially lead to adverse effects on the endocrine system.[1,2] Several studies have shown that BPA interacts with hormones in the human body, and stimulates estrogen production, which increases susceptibility to breast[8-10] and prostate cancer,[11-13] and affects learning and memory.[14] In addition, exposure to BPA during childhood is associated with higher levels of anxiety, depression, hyperactivity, and inattention.[15] Avoding exposure to BPA during early childhood is critical because children are more susceptible to its adverse effects.[16]

Orthodontists repeatedly expose their patients to BPA-containing materials such as resins, and adhesives.[16] The systemic ingestion of BPA particles may increase owing to the use of bracket and lingual-retention bonding agents and resin acrylic in orthodontic devices, which remain in the oral cavity for several years.[17] BPA release from orthodontic composites occurs during or shortly after insertion owing to incomplete material polymerization. In addition, these materials are exposed to mechanical wear, thermal and pH changes, and enzymatic degradation, resulting in further BPA release.[16,17]

Several studies have evaluated the effects of BPA ingestion after insertion of orthodontic appliances;[16-20] however, they focused on BPA release from adhesive composites used for orthodontic bracket bonding, and BPA release from orthopedic devices remains poorly investigated. Orthopedic devices such as the Haas expander include a combination of orthodontic bands and acrylic components.[21] Orthodontic bands are generally installed using bisphenol A Glycidyl methacrylate-based composites, and BPA is the main component of this monomer.[22] Additionally, BPA release from the acrylic components of orthodontic devices has been reported.[23-26]

Considering the scarcity of studies and the fact that younger patients are more susceptible to the potentially deleterious effects of BPA, studies on the early exposure of children to orthodontic devices are warranted. Therefore, this study aimed to evaluate the salivary BPA levels in children undergoing orthodontic treatment with Haas expanders.

MATERIALS AND METHODS

The ethics committee of the Dental School of Ribeirão Preto, University of São Paulo, Brazil approved this study (Approval No., 29820520.3.0000.5419). Free informed consent was obtained from all participants and their legal guardians.

The sample size was calculated using SPSS Sample Power software (IBM Corp., Armonk, NY, USA). The Student's *t* test was applied to one sample case. Based on the results ($\beta = 0.20$; $\alpha = 0.05$, Cohen's d effect size = 0.65), the minimum sample size for this study was calculated as 20 patients.[16] The inclusion criteria were children aged 6–10 years with good general health, and fully erupted bilateral maxillary first permanent molars and skeletal posterior crossbite with an indication for rapid maxillary expansion. Patients with dental caries and/or periodontal disease or composite resin restorations or sealants placed in the previous 3 months were excluded.

Elastics (Dental Morelli, Sorocaba, Brazil) were inserted in the mesial contact areas of the maxillary first permanent molars of the selected patients to achieve separation. One week later, orthodontic bands (Dental Morelli) were adapted and a maxillary impression was obtained using alginate impression material (Dentsply Sirona, Charlotte, NC, USA). Plaster models (Asfer, São Caetano do Sul, Brazil) with transferred bands were obtained, and Hass expanders were fabricated.

The expanders were installed with the same amount of acrylic monomer for each participant (four bonding points with composite resin in each hemi-arch, totaling 8 points in the upper arch). The bands were cemented using Transbond Plus Light Cure Band (3M ESPE, Monrovia, CA, USA), which was light-cured for 40 seconds using a halogen light-curing unit at an intensity of 450 mW/cm. The metallic structures were bonded using Transbond XT Light Cure Adhesive Prime adhesive (3M ESPE) or Transbond XT composite (3M ESPE), which were light-cured for 40 seconds.

Thirty minutes before cementing the modified Haas expander (T0), 1 mL of non-stimulated saliva was collected. The saliva was stored in amber glass tubes to assess the amount of pre-treatment BPA level. Thirty minutes after expander insertion (T1), a second 1-mL sample of non-stimulated saliva was collected. Additional 1-mL samples of non-stimulated saliva were collected 24 hours (T2), 1 week (T3), and 1 month (T4) after appliance insertion. All samples were sequentially frozen at

–80°C, until the last collection.

Saliva samples (800 μL) were enriched with 50 μL (100 ng/mL) of the internal standard (bisphenol-d16) and extracted twice using 600 μL of methyl tert-butyl ether. The solution was vortexed for 30 seconds (3,000 rpm) and centrifuged for 10 minutes (13,000 rpm) to achieve phase separation. The organic phase was then transferred to an Eppendorf tube and evaporated. The dry extract was reconstituted in 100 μL of water:methanol solution (60:40 [v/v]) and transferred to vials containing glass inserts.

Ultra-high-performance liquid chromatography coupled with Tandem Mass Spectrometry (UHPLC-MS/MS) (including sample preparation by liquid–liquid extraction), as previously validated according to the current international guidelines of the European Medicines Agency and Food and Drug Administration, was performed to quantify the amount of BPA in the samples. BPA levels were assessed using the Waters ACQUITY UPLC H-Class system coupled to the Xevo® TQ-D tandem quadrupole (Waters Corporation, Milford, MA, USA) mass spectrometer equipped with a Z-spray source operating in negative electrospray ionization mode. Processed samples were placed in the automatic injector at 10°C, and 10 μL of the sample was automatically injected into the ACQUITY UPLC® CSH™ C18 chromatographic column (1.7 μm, 2.1 × 100 mm) at 40°C. The mobile phase was a mixture of solvents A (water) and B (methanol) at a flow rate of 200 μL min-1. The elution gradient consisted of 40% B (0 minute), 40–70% B (6 minutes), and 40% B (8 minutes), followed by 4 minutes to equilibrate the chromatographic column. The total chromatographic run time was 12 minutes.

The mass spectrometer was operated under the following conditions: capillary voltage, 3.5 kV; source temperature, 150°C; desolvation temperature, 450°C; desolvation gas (N_2, 99.9% purity) flow, 900 L/hr; and cone gas (N_2, 99.9% purity) flow, 5 L/hr. Argon (99.9999% purity) was used as collision gas. Data were acquired using MassLynx V4.1 software (Waters Corporation). Both the analyte and internal standard were analyzed in the selected reaction monitoring mode. The specific transitions used for each analyte are listed in Table 1. The first transition was used for quantitative purposes, and the second transition was used to confirm the respective analytes.

The Shapiro–Wilk test was used to verify the normality of the results of the saliva examinations, and the data showed a normal distribution. The results were described using means and standard deviations, and the difference between the experimental periods was verified using one-way analysis of variance with Tukey's post-hoc test. Statistical analysis was performed using GraphPad Prism version 9 (GraphPad Software Inc., San Diego, CA, USA), and statistical significance was set at 5% ($P < 0.05$).

RESULTS

This study enrolled 39 patients. The appliance failed in 13 patients, which led to its removal before the end of the experiment. One patient developed a palatal lesion, and saliva samples from three patients were discarded because of temperature changes. Finally, data from 22 children (11 boys and 11 girls; mean age, 8.32 ± 3.80 years) were included in the analysis.

Data regarding the salivary BPA levels over time are shown in Table 2 and Figure 1. Chromatography analysis revealed that the mean BPA level in saliva samples at T0 was 0.475 ng/mL. Salivary BPA levels significantly increased to 70.324 ng/mL ($P < 0.05$) at T1, which was significantly higher than those at other time points. Furthermore, BPA levels at T2 were significantly higher ($P < 0.05$), than those at T0 (18.015 ng/mL), T3 (2.764 ng/mL), and T4 (0.625 ng/mL). However, BPA levels were not significantly between T0, T3, and T4 ($P > 0.05$).

DISCUSSION

To the best of our knowledge, this is the first study to evaluate BPA release from an orthopedic device. This study showed that BPA levels in the saliva significantly increased 30 minutes after insertion of the Haas expander. After 24 hours, although BPA levels reduced, they remained significantly higher than those at baseline. After 1 week, BPA levels reached close to the initial levels. Our results indicate that BPA release after Haas installation occurs because of the first contact with the acrylic resin and incomplete polymerization of the com-

Table 1. Tandem Mass Spectrometry transitions selected to the reaction by monitoring mode in electrospray ionization

Analyte	Ion precursor (m/z)	Ion product (m/z)	CV (V)	CE (eV)	t_R (min)
BPA	227.0	212.1	45	20	5.1
	227.0	132.9	45	24	
BPA_d16	241.1	141.9	45	22	5.1
	241.1	223.3	45	20	

CV, cone voltage; CE, collision energy; t_R, retention time; BPA, bisphenol A.

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Table 2. Comparison of mean BPA levels at different timepoints

Experimental time	BPA salivary levels (ng/mL^{-1})			*P* value				
	Minimum	Maximum	Mean (SD)	T0	T1	T2	T3	T4
T0	0.079	1.300	0.475 (0.27)	-	< 0.001*	0.010*	0.993	< 0.999
T1	22.070	159.223	70.324 (37.05)	< 0.001*	-	< 0.001*	< 0.001*	< 0.001*
T2	3.136	39.133	18.015 (11.22)	0.010*	< 0.001*	-	0.036*	0.011*
T3	0.455	6.333	2.764 (1.74)	0.993	< 0.001*	0.036*	-	0.994
T4	0.123	2.248	0.625 (0.40)	< 0.999	< 0.001*	0.011*	0.994	-

ANOVA with Tukey's post-hoc test was performed.
Before (T0) and 30 minutes (T1), 24 hours (T2), 1 week (T3), and 1 month (T4) after Haas expander installation.
BPA, bisphenol A; SD, standard deviation.
*$P < 0.05$.

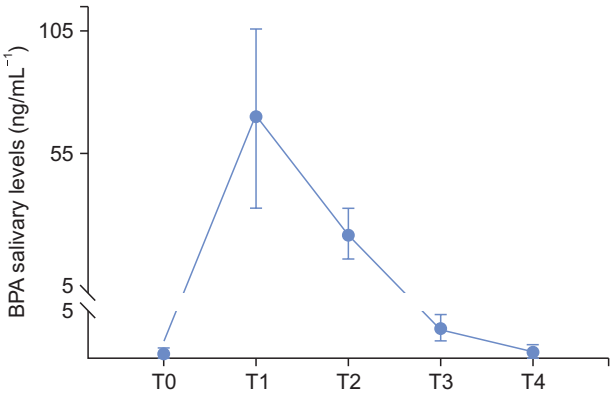

Figure 1. Line graph showing salivary levels of bisphenol A (BPA) at different timepoints during the experiment. Before (T0) and 30 minutes (T1), 24 hours (T2), 1 week (T3), and 1 month (T4) after Haas expander installation.

posite.[16-26]

We quantified salivary BPA levels using the UHPLC-MS/MS method, which has been shown to be highly accurate for this type of investigations.[26-29] This method is a powerful next-generation analytical tool with high detectability and reproducibility, and is ideal for quantifying non-volatile molecules present at trace levels in biological samples. Moreover, the tandem MS/MS configuration provides high specificity using two stages of mass analysis. Improved resolution and efficiency lead to shorter analysis times, reduced potential for human error, and greater overall reliability.[26-29]

Despite the significant increase in BPA levels immediately after appliance installation, BPA levels did not exceed the TDI established by the EFSA in 2023.[6] However, several studies have demonstrated BPA activity at doses lower than the reference level,[6,13] and increased prostate weight and other effects on the male reproductive system were observed in mice at BPA doses of 2 and 20 mg/kg, respectively.[30,31] Although some studies[32,33] have reported that BPA is completely eliminated via the urine within 48 hours, regular exposure to smaller BPA doses may be as harmful as that to occasional high doses.[6] Clinicians should not only consider BPA release from dental materials alone but also the sum of exposures from all sources to which children may be potentially exposed. Therefore, contributing to BPA accumulation is not desirable, especially in children, who are notably more susceptible. Recently, children have been seeking orthodontic treatment earlier, usually at the beginning of mixed dentition; thus, and additional BPA exposure due to orthodontic appliance installation may increase the risks compared to those in adults.[15,16]

Several studies have suggested a high risk of oncogenesis in humans with BPA exposure;[8-13] however, further studies are required to understand the interactions of BPA with human structures and its adverse effects. We endorse previous recommendations[34,35] to reduce potential BPA release from orthodontic devices, such as polishing the acrylic resin adequately, positioning the curing light close to the composite (1–3 mm) at a 45–60° angule, light-curing around the edges of the orthodontic appliances, and instructing patients to rinse their mouths with a mouthwash or water during the first hour after orthodontic device installation.

This study has some limitations. Patients are normally expected to encounter BPA sources during their daily activities, such as drinking liquids from plastic cups or water gallons, heating food in plastic containers, or drinking from plastic bottles. We did not control the diet of the study sample, which may have resulted in BPA exposure from sources other than those evaluated. To eliminate these confounding factors, saliva samples were collected before appliance insertion to generate reference values. For ethical reasons, we did not conceive this study as a randomized clinical trial, considering that posterior crossbites are treated more effectively when approached as early as possible.[21] Future studies should evaluate BPA release from other orthodontic devices,

such as the Hyrax and McNamara expanders.

CONCLUSIONS

Within the limitations of this study, it can be concluded that:

- Salivary BPA levels significantly increase after installation of the Haas orthodontic expander. However, BPA levels do not exceed the TDI.
- Salivary BPA levels are the highest 30 minutes after installation of the Haas orthodontic expander and return to baseline values after 30 days.

AUTHOR CONTRIBUTIONS

Conceptualization: MANM. Data curation: CLBR. Formal analysis: VOP, MEQN, IDS, KCH, APVA. Funding acquisition: MANM. Investigation: VOP, PNF. Methodology: MANM. Project administration: MANM. Resources: MANM. Software: MANM. Supervision: FLR, MBSS, MANM. Validation: FLR, MBSS, MANM. Visualization: PNF, FLR, MBSS, MANM. Writing–original draft: VOP, PNF, CLBR. Writing–review & editing: All authors.

CONFLICTS OF INTEREST

No potential conflict of interest relevant to this article was reported.

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