

# Forever Chemicals in Teeth: PFAS Presence and Dental Mineralization

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## Background

- Per- and polyfluoroalkyl substances (PFAS), commonly referred to as "forever chemicals," are ubiquitous environmental contaminants.
- Thousands of PFAS exist, but PFOA (perfluorooctanoic acid) and PFOS are the most common (perfluorooctanoic sulfonic acid).<sup>1</sup>
- PFAS have historically been used in firefighting foams, waterproofing materials, grease-resistant papers and wrappers, industrial sites, and foods due to bioaccumulation.<sup>1,2</sup>
- Despite the EPA limitations in place, PFAS are still commonly found in drinking water, particularly PFOA and PFOS.<sup>2</sup>
- PFAS has been identified in multiple human organ systems, with PFOS commonly found in the blood, brain, liver, kidney, and lungs<sup>4,5</sup> and PFOA more commonly found in bone.<sup>4</sup>
- PFAS has also been found in fetal and placental tissues, showing that PFAS can cross the placenta.<sup>4</sup>
- Environmental and systemic factors impact tooth development, including systemic illness in the first 3 years of life, antibiotic usage, gestational age, and complications during pregnancy.<sup>6, 7</sup>
- The presence and potential effects of PFAS in teeth have not yet been investigated.

## Aim

Evaluate the association between hypomineralization (HM) and PFAS concentrations in town drinking water.

## Methods

- A retrospective chart review was conducted for patients who received orthodontic treatment at Boston Children's Hospital between 2010 – 2024. Relevant charts were identified from Dentrix Enterprise software (Version 8.0.0.203).
- PFAS testing levels in public water by town were obtained from Sierra Club's Massachusetts Chapter. Up to 18 different PFAS were included in the testing and reported in parts per trillion (ppt).
- Low PFAS towns were defined as <20ppt in accordance with the MA cutoff<sup>9</sup> and then as <70ppt in accordance with the EPA cutoff.<sup>10</sup>
- Clinical variables included patient demographics (sex, age, race, ethnicity, insurance, town), medical history, PFAS level of the patient's town's tap water supply, and the presence of hypomineralization (HM) identified from orthodontic intraoral photos.

## Methods

Inclusion criteria:

- At least 1 complete set of Orthodontics photos (frontal, left buccal, right buccal, maxillary occlusal, mandibular occlusal)
- Patient is from a town with publicly available PFAS data reporting at least 12 out of 18 PFAS compounds
- 878 eligible subjects were reviewed

Statistical Analysis:

- A multivariable logistic regression model (backward stepwise selection) was used to predict HM presence.
- P-values < 0.2 were considered in the multivariate models and P-values < 0.1 were considered significant.

## Results

Descriptive Statistics for Model Selection

	HM Absent (N = 468)	HM Present (N = 410)	P-value
Age at Last Photo (Years)	14.0 (4.0, 29.0)	14.0 (6.0, 29.0)	0.300
Sex			0.600
Female	213 (46%)	179 (44%)	
Male	255 (54%)	231 (56%)	
Race			0.014
Caucasian	181 (46%)	207 (56%)	
Asian	35 (8.9%)	28 (7.5%)	
Black	84 (21%)	49 (13%)	
American Indian	1 (0.3%)	2 (0.5%)	
Other	92 (23%)	85 (23%)	
Unknown	75	39	
Ethnicity			0.100
Hispanic	96 (24%)	70 (19%)	
Non-Hispanic	300 (76%)	295 (81%)	
Unknown	72	45	
Insurance			0.048
Private	137 (29%)	145 (35%)	
Public	294 (63%)	220 (54%)	
Both	16 (3.4%)	20 (4.9%)	
None	21 (4.5%)	25 (6.1%)	
Unknown	199	154	

Table 2: Patient Clinical Characteristics, by HM

	HM Absent (N = 468)	HM Present (N = 410)	P-value
Premature			>0.900
Yes	34 (12%)	33 (12%)	
No	257 (88%)	245 (88%)	
Unknown	177	132	
Antibiotics Prescribed Under 1yo			0.700
Yes	107 (46%)	103 (44%)	
No	126 (54%)	131 (56%)	
Unknown	235	176	
Number of Antibiotics Prescribed Under 1yo	0.00 (0.00, 8.00)	0.00 (0.00, 7.00)	0.800
Unknown	235	176	
Any Fever Under 6yo			0.063
Yes	131 (49%)	104 (41%)	
No	138 (51%)	152 (59%)	
Unknown	199	154	
Number of Fevers Under 6yo	0.00 (0.00, 8.00)	0.00 (0.00, 7.00)	0.045
Unknown	199	154	
Relevant Medical History (Select All that Apply)			
Asthma / Bronchitis	60 (13%)	55 (13%)	0.800
Thyroid / Hypoparathyroid	11 (2.4%)	7 (1.7%)	0.500
Cancer / Hx of Radiation/Chemotherapy	5 (1.1%)	4 (1.0%)	>0.900
Cleft	94 (20%)	144 (35%)	<0.001
Heart Conditions	27 (5.8%)	32 (7.8%)	0.200
Otitis Media (first < 3yo)	84 (18%)	80 (20%)	0.600
Otitis Media (first ≥ 3yo)	37 (7.9%)	41 (10%)	0.300
Celiac Disease	2 (0.4%)	2 (0.5%)	>0.900
Nutritional Deficiencies / Malnourished	15 (3.2%)	13 (3.2%)	>0.900
Muscular Dystrophy	2 (0.4%)	0 (0%)	0.500
Cerebral Palsy	5 (1.1%)	1 (0.2%)	0.200
Cystic Fibrosis	2 (0.4%)	1 (0.2%)	>0.900
Syndromic Craniofacial Dysmorphism	46 (9.8%)	57 (14%)	0.061
No Relevant Medical History	28 (6.0%)	39 (9.5%)	0.049
Other Medical Complexities	214 (46%)	144 (35%)	0.001
Other Medical Complexities	162 (35%)	144 (35%)	0.900

<sup>1</sup> n (%), Median (Min, Max); <sup>2</sup> Pearson's Chi-squared test; Fisher's exact test

Medical History Factors included in multivariable model:

- Fever under the age of 6yo
- Cleft
- Syndromic Dx
- Craniofacial syndromic Dx

## Results (continued)

Continuous PFAS Model: Logistic Regression Model Predicting Hypomineralization (HM) Presence

- In an unadjusted model, the data set does not indicate that continuous PFAS levels are associated with HM presence.

Table 3: Continuous PFAS, Unadjusted Logistic Regression Model Predicting HM Presence

Variable	Odds Ratio	CI	P-value
PFAS Level (ppt)	1.00	1.00 - 1.00	0.164
Observations	878		

- In an adjusted model, the data set does not indicate that continuous PFAS levels are associated with HM presence.

Table 4: Continuous PFAS, Adjusted Logistic Regression Model Predicting HM Presence

Variable	Odds Ratio	CI	P-value
PFAS Level (ppt)	1.00	1.00 - 1.00	0.363
Cleft: Yes	1.76	1.24 - 2.50	0.001
Race: Asian (ref = Caucasian)	0.70	0.40 - 1.21	0.200
Race: Black (ref = Caucasian)	0.59	0.38 - 0.91	0.018
Race: Other (ref = Caucasian)	1.19	0.76 - 1.87	0.455
Ethnicity: Hispanic (ref = Non-Hispanic)	0.66	0.42 - 1.04	0.074
Observations	878		

MA Cutoff PFAS Model: Logistic Regression Model Predicting Hypomineralization (HM) Presence

- In an unadjusted model, the data set does not indicate that the MA Cutoff of PFAS levels are associated with HM presence.

Table 5: MA PFAS Categorization, Unadjusted Logistic Regression Model Predicting HM Presence

Variable	Odds Ratio	CI	P-value
MA PFAS Categorization (High)	1.06	0.80 - 1.40	0.681
Observations	878		

- In an adjusted model, the data set suggests that patients in high PFAS towns (MA Cutoff) have an 11% higher odds (95% CI 0.80-1.53, p=0.536) of having HM, but insignificantly so. Patients with cleft have 75% higher odds of having HM when compared to patients without cleft. Black patients have a significantly lower odds of having HM when compared to white patients.

Table 6: MA PFAS Categorization, Adjusted Logistic Regression Model Predicting HM Presence

Variable	Odds Ratio	CI	P-value
MA PFAS Categorization (High)	1.11	0.80 - 1.53	0.536
Cleft: Yes	1.75	1.24 - 2.49	0.002
Race: Asian (ref = Caucasian)	0.68	0.39 - 1.19	0.181
Race: Black (ref = Caucasian)	0.58	0.37 - 0.89	0.014
Race: Other (ref = Caucasian)	1.18	0.75 - 1.86	0.476
Ethnicity: Hispanic (ref = Non-Hispanic)	0.66	0.42 - 1.05	0.082
Observations	699		

## Results (continued)

EPA Cutoff PFAS Model: Logistic Regression Model Predicting Hypomineralization (HM) Presence

- In an unadjusted model, the data set suggests significance between PFAS levels at the EPA Cutoff of 70ppt and HM presence.

Table 7: EPA PFAS Categorization, Unadjusted Logistic Regression Model Predicting HM Presence

Variable	Odds Ratio	CI	P-value
EPA PFAS Categorization (High)	1.50	1.02 - 2.22	0.040
Observations	878		

- In an adjusted model, the data set suggests that patients in high PFAS towns (defined by the EPA Cutoff of 70ppt) have a 42% higher odds (95% CI 0.91-2.23, p=0.122) of having HM, but not significantly so. Again, patients with cleft have higher odds of HM and black patients have lower odds of HM.

Table 8: EPA PFAS Categorization, Adjusted Logistic Regression Model Predicting HM Presence

Variable	Odds Ratio	CI	P-value
EPA PFAS Categorization (High)	1.42	0.91 - 2.23	0.122
Cleft: Yes	1.76	1.24 - 2.50	0.002
Race: Asian (ref = Caucasian)	0.70	0.40 - 1.21	0.199
Race: Black (ref = Caucasian)	0.61	0.39 - 0.94	0.026
Race: Other (ref = Caucasian)	1.19	0.76 - 1.88	0.451
Ethnicity: Hispanic (ref = Non-Hispanic)	0.67	0.42 - 1.06	0.093
Observations	699		

## Conclusion

There is a trend towards more HM presence in high PFAS towns.

## Next Steps

- Expand chart review of eligible patients.
- Scan collected sample teeth with Raman microspectroscopy to evaluate presence and localization of PFAS.

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