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The Comparative Analysis of the Salivary Biomarker's level Between Different Areas with Air Pollutant PM2.5, in Ulaanbaatar, Mongolia

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ABSTRACT:

Background/purpose: Ulaanbaatar, the capital of Mongolia, is one of the coldest and most polluted cities globally, with PM2.5 concentrations five times higher than WHO guidelines. PM2.5 enters the body via the respiratory tract and damages multiple organs, including the oral cavity. This study aimed to compare salivary biomarker levels among 12 year old children living in areas with different PM2.5 concentrations in Ulaanbaatar.

Materials and Methods: A cross sectional study enrolled 190 children from schools in the highest (study) and lowest (control) PM2.5 areas, selected using four year air quality data. Oral examinations followed WHO criteria, OHI S, Loe Silness gingival index, and PPD assessment. Saliva from 45 children (stratified by PM2.5 and oral health status) was analyzed for F_2 isoprostane, 8 OHdG, and TAC via ELISA. SPSS v29 was used for statistics.

Results: Caries prevalence was 91.0%, mean DMFT 5.29±3.49 and DT comprised 84.9% of DMFT. OHI S score averaged 1.85±1.29, significantly worse in the study group ($p<0.01$). Gingivitis affected 23.2% overall (25.2% study vs. 20.5% control). Children with PPD ≥3 mm were significantly more common in the high PM group (57.8% vs. 42.1%,

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p=0.040). Salivary 8 OHdG was the most sensitive combined burden marker, showing a 2.6 fold increase in the high PM+disease group versus low PM+healthy (447.63 vs. 172.22 pg/mL, p<0.001). TAC was markedly depleted in both disease groups, whereas F_2 isoprostane showed an unexpected inverse association with PM exposure.

Conclusion: Significantly higher caries/gingivitis and altered salivary biomarkers in high PM children underscore environmental factors in oral disease and the urgent need for public health action.

INTRODUCTION

Ulaanbaatar is the capital city of Mongolia and is one of the coldest capitals,[1] as well as one of the most polluted city in the world[2,3] and second in the East Asia.[2] It is five times higher than World Health Organization (WHO) guideline for fine particular matter 2.5 (PM2.5) pollution.[3] This high concentration of fine particulate matter violates health of the overall population of Ulaanbaatar and, in particular, the right of children to grow, develop, and to live in a safe and healthy environment.[4] WHO reported that the most harmful air pollutant to human health is PM2.5.[5] Numerous studies have confirmed that these fine particulate matters enter the human body through the respiratory tract causing serious damage to the lungs,[6,7] heart,[7] brain, kidneys, and digestive organs,[8] as well as to the oral cavity, including periodontal diseases,[9,10] oral cancer,[11] dental caries,[10,11] and various other oral conditions.[12] The literature review had confirmed the association between air pollutants and oral diseases; especially PM2.5 can decrease oral immunity,[13] and is associated with periodontal disease.[12]

Unlike blood tests, saliva collection is painless, simple, and can be repeated frequently to track the progression of oral diseases.[14] Saliva is a diagnostic tool as a significant advancement in medical science, offering a non-invasive and cost-effective method for disease detection and monitoring.[15] Saliva contains a dynamic pool of molecular markers that reflect both local oral diseases and systemic responses to PM2.5.[16]

This study aimed to compare the salivary biomarker's level among 12 years old children, living in the different areas with air pollutant PM2.5 in Ulaanbaatar city, Mongolia

MATERIALS AND METHODS

The study design was cross-sectional study. The study population consisted of 190 children aged 12 years old, according to the consent form numbered 24-25/10-1, approved by the Ethical Committee of MNUMS. The children were selected from the secondary school, which is located in the highest (study group) and lowest (control group) PM2.5 level in Ulaanbaatar city, Mongolia. The school location was selected based on air quality indicators from the past four years provided by the National Agency for Meteorology and Environmental Monitoring.[17]

Oral examination was performed according to the WHO 2013 recommendation, [18] the oral hygiene index-simplified (OHI-S),[19] the gingival index by using Loe and Silness method (1963),[20] and periodontal pocket depth (PPD) according to the AAPD periodontal guidelines[21] in all 190 children. Saliva sample collected from 45 children, who were selected from study and control groups based on similarity of the decayed teeth and gingival index (subgroups noted by X-low PM2.5; T-high PM2.5; 1-Healthy teeth and gum, 2-Decayed teeth and gingivitis). The salivary biomarkers were determined using ELISA kit (*Sunlong Biotech Co., LTD* Human F_2-isoprostane, Total Antioxidant Capacity (TAC), Human 8-Hydroxy-desoxyguanosine (8-OHdG)) in the biochemical laboratory of MNUMS.

Statistical analysis

Statistical analysis was performed using SPSS software version 29 (SPSS Inc., Chicago, IL, USA). Normality was assessed using the Shapiro–Wilk test. Between-group comparisons were performed using independent t-tests or Mann–Whitney U tests. For multiple group comparisons, one-way ANOVA with Kruskal–Wallis or with Dunn's post-hoc correction was used. Categorical variables were compared using chi-square or Fisher's exact tests. Two-way ANOVA was used to assess the main effects and interaction of PM2.5 exposure and oral disease status on salivary biomarkers. Spearman's correlation was used to assess associations between biomarkers and clinical parameters. A p-value < 0.05 was considered statistically significant

RESULTS

Outcomes of dental health evaluation

The prevalence and mean DMFT score of dental caries were 91% and 5.29±3.49 among all children; 96% and 5.34±3.98 in the study group, and 87% and 5.23±2.76 in the control group ($p<0.05$), respectively (Table 1).

Outcomes of OHI-S evaluation

The mean OHI-S score was 1.85±1.29, it evaluated the "fair". The OHI-S score in the study group was significantly higher than the control group ($p<0.01$) (Table 2).

Outcomes of gingival index and PPD evaluation

The incidence of gingivitis was 23.2% among all children, 25.2% (27) in the study group and 20.5%(17) in the control group. The mean DMFT score in the children with gingivitis was higher than healthy gum, significantly ($p<0.05$) (Table 3).

Table 1 and 3 had shown the decayed teeth score was the majority of the mean DMFT score.

Assessing of periodontal status by analyzing the mean PPD for each child, the average PPD was 1.94±0.77 mm in study group and 1.90±0.88 mm in the control group ($p=0.893$), but 1.70±0.74 mm in the healthy gum group and 2.62±0.66 mm in the gingivitis group ($p=0.001$) (Table 4).

Outcomes of salivary biomarkers

The salivary F_2-isoprostane, 8-hydroxydeoxyguanosine (8-OHdG) and total antioxidant capacity level were determined among 45 children and compared between subgroups (X1, X2, T1 and T2) in the Table 5.

Table 5 shows the salivary 3 biomarkers in the stratified analysis by PM2.5 exposure and oral disease status between the four subgroups. Overall, 8-OHdG emerged as the most sensitive marker for detecting the combined burden of PM2.5 and oral disease, while F_2-isoprostane showed an unexpected inverse association with PM exposure, and TAC depletion was primarily attributable to oral disease status.

DISCUSSION:

Mongolia is a landlocked central Asian country sandwiched between two giants, Russia and China. It has over 3.5 million people living in a vast mass of land and is one of the few remaining countries in the world where there is a combined sedentary and nomadic lifestyle. The cold season in Mongolia can be very long, extending from October to March/April,[22] and it is very cold. Mongolia's population is highly urbanized, with more than half of the total population living in the capital city, Ulaanbaatar (approximately 1.6–1.7 million out of 3.5 million.[23] More than 60% of Ulaanbaatar's total population lives in the ger district, a peripheral area characterized by traditional felt tents and lack of centralized infrastructure.[24] The Ger district consists mostly of tiny houses and ger (a Mongolian traditional yurt-like round housing) not connected to the central heating system. Thus, Ger residents burn raw coal in traditional iron stoves for heating during the cold season and often for cooking. Indeed, households and low-pressure boilers burning raw coal in the Ger district account for 80% of total air pollution in Ulaanbaatar during the winter, with emissions from coal-fired power plants and motor vehicle exhaust playing a secondary role.[25]

In the present study, the overall prevalence of dental caries was 91.0%, with a mean DMFT index of 5.38 per child. Based on the WHO criteria for caries severity classification, this value falls into the "high" severity category.[18] The high proportion of untreated decayed teeth (84.9% of DMFT) observed in our study is consistent with global patterns reported by the WHO, which indicate that 60–90% of children worldwide experience dental caries, with the majority left untreated due to inadequate dental care infrastructure.[26] This disparity is further reflected in income-level differences: in high-income countries, approximately 50% of carious lesions receive treatment, compared to only 2% in low-income countries.[27] Similar results have been documented in other countries. A Turkish study among 8–10-year-olds reported a caries prevalence of 96.1% and a PUFA index of 13.3%.[28] In India, 47.3% of younger children (6–10 years) and 18% of older children (11–15 years) had complications from untreated caries, including pulp involvement.[29] The high D component in our study (84.9%) is consistent with these findings, suggesting that limited access to restorative care and preventive interventions is a shared challenge across many low- and middle-income countries. The mean OHI-s score was categorized as "fair" oral hygiene according to standard criteria. This reflects suboptimal tooth brushing habits and inadequate oral care practices among the study children, which may partially explain the high burden of dental caries and gingival inflammation observed in this population. Before 10 years ago, in Mongolia the same results were published.[30]

Our finding of a higher proportion of children with gingivitis in the high PM2.5 exposure area is consistent with previous studies from China.[12,13] These study reported significant associations between PM2.5 exposure and increased risk of gingival inflammation, suggesting that air pollution may contribute to periodontal disease through systemic inflammatory mechanisms. Marruganti C. et al reported that increasing levels of air pollution were associated with a higher prevalence of periodontal disease, including periodontal pocket depth and clinical attachment loss in South Korea.[31] In our study, we similarly observed that the proportion of children with PPD $\geq$ 3 mm was significantly higher in the high PM2.5 exposure group (57.8% and 42.1%, $p = 0.040$). This consistency supports the growing evidence that ambient air pollution, particularly PM2.5, may be a contributing environmental risk factor for periodontal tissue inflammation.

We found statistically significant relationships between air pollution and salivary levels of F_2-isoprostane, 8-OHdG, and total antioxidant capacity (TAC). These results are consistent with international studies showing that PM2.5 exposure induces oxidative stress, characterized by increased lipid peroxidation and DNA damage, and reduced antioxidant reserves. As demonstrated by Marnett L.J.[32] and Milne G.L.[33], is a reliable marker of lipid peroxidation, and 8-OHdG is a sensitive indicator of DNA oxidative damage. Elevated levels of these biomarkers reflect increased oxidative stress; we observed significantly higher F_2-isoprostane and 8-OHdG levels in children with high PM2.5 exposure in the oral disease area in our study.

The present study provides evidence that the children residing in areas with elevated ambient air pollution experience a greater burden of oral health problems, characterized by increased prevalence and mean DMFT score of dental caries and gingival inflammation. Furthermore, significant alterations in salivary oxidative stress and antioxidant biomarkers suggest that chronic PM2.5 exposure may contribute to oral pathological processes through mechanisms involving oxidative damage, inflammatory responses, and impairment of endogenous antioxidant defense systems. These findings are consistent with growing evidence linking air pollution to adverse oral and systemic health outcomes and support the hypothesis that oxidative stress may be a key biological pathway underlying these associations. Collectively, these findings underscore the importance of considering environmental determinants, in addition to traditional behavioral and socioeconomic risk factors, in the prevention and management of oral diseases.

Nevertheless, several limitations should be acknowledged. First, the cross-sectional nature of the study precludes causal influence and limits the ability to establish temporal relationship between PM2.5 exposure, biomarker alterations, and oral health outcomes. Second, the relatively small sample size used for biomarker analyses may have reduced statistical power and limited the generalizability of the findings. Third, exposure assessment was based on area-level air pollution data, which may not accurately reflect individual exposure levels and could have resulted in exposure misclassification. Finally, although major variables were considered, residual confounding from unmeasured factors, including dietary habits, indoor air pollution exposure, oral hygiene practices, socioeconomic status, and other environmental determinants, cannot be excluded.

Future research should employ prospective longitudinal cohort designs to clarify the temporal and causal relationship between air pollution exposure and oral health outcomes. The incorporation of individual-level PM2.5 monitoring, comprehensive assessment of potential confounding factors, and expanded panels of oxidative stress, inflammatory, and immunological biomarkers would provide a more comprehensive understanding of the underlying biological mechanisms. In addition, intervention studies aimed at reducing exposure to air pollution or mitigating its biological effects are warranted to generate evidence for effective public health strategies and evidence-based preventive measures for protecting children's oral health. We concluded that the findings of this study, exposure to elevated levels of ambient air pollution was associated with increased prevalence and mean DMFT score of dental caries and gingival inflammation among 12-year-old children. Significant difference in salivary oxidative stress biomarkers further support the potential role of air pollution in the pathogenesis of oral diseases. These findings highlight the importance of incorporating environmental health considerations into oral disease prevention and child health promotion programs.

Declaration of competing interest

The authors declare no conflicts of interest.

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