OXFORD JOURNAL
OF STUDENT
SCHOLARSHIP

Dental Microplastics Negatively Impact the Digestive and Respiratory Systems

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ABSTRACT

Humans are increasingly exposed to microplastics through daily oral hygiene routines and dental procedures performed with plastic materials. Microplastics have been proven to cause negative health effects, especially to the organs of the digestive and respiratory systems. Although many studies have investigated the impact of microplastics on the human body, few have specifically examined the effects of dental microplastics. In this review, the effects of polyethylene, polymethylmethacrylate, and other dental microplastics on the digestive and respiratory systems were researched. In the digestive system, polyethylene and polymethylmethacrylate microplastics were found to cause higher reactive oxygen species levels, leading to oxidative stress and inflammation. In the respiratory system, polymethylmethacrylate also causes higher reactive oxygen species levels, oxidative stress, and inflammation in lung macrophage cells, altogether reducing cell vitality. This review demonstrates the consequences of microplastic use in the dental industry and highlights the importance of high-impact research on biocompatible alternatives. In addition, more *in vivo* studies on human patients are needed to understand the short-term and long-term effects caused by dental microplastics. Increased awareness of these negative health effects will push the dental industry toward a safer and more sustainable future.

Keywords: Medical and Health Sciences, Dentistry, Dental Microplastics, Inflammation, Cellular Stress.

INTRODUCTION

It has been estimated that human exposure to microplastics by inhalation could be as high as 3000 particles per day.[1] Plastics are used in almost every industry, and alarm bells are being raised due to their potential negative impact on human health. Concerns have already been raised about the microplastic threat in terrestrial and marine ecosystems.[2] Microplastic exposure can come from anywhere. Microplastics can be inhaled, ingested through food, and even absorbed through our skin and eyes, leading to an accumulation in the organs of the digestive and respiratory systems.[3] Inhaled microplastics can increase the risk for lung conditions such as pneumonia.[4] Microplastics have even been found circulating in the bloodstream of humans.[5,6] This is very concerning, as emerging research has found that microplastics clearly cause a variety of negative health problems, but these concerns are often left unaddressed by the industries that remain reliant on plastics.

The dental industry uses a lot of plastic products, including toothbrushes, floss, aligners, and dental implants.[7,8] In particular, plastic is popular for aligners due to their ease of use and comfort.[9–11] These plastics wear down over time, exposing users to microplastics that can be absorbed into their bodies.[12,13] Microplastic exposure comes from everyday oral hygiene routines or dental procedures. Toothpaste and toothbrushes, for example, were found to be a significant source of microplastic exposure.[14,15] Microplastic exposure can also come from dental procedures. In many of these cases, the dental practitioner is more exposed to these particles, rather than the patient. One plastic that is widely used in dentistry is called polymethylmethacrylate (PMMA).[16] PMMA plastic is used in dental aligners, and as a result, the digestive tract is exposed to microplastics produced by the aligners as they are ingested.[17] PMMA microplastics can also be inhaled, going down the respiratory tract.[18]

Despite the dental industry's heavy use of plastic, research to understand the physiological effects of microplastic absorption resulting from its use remains limited. It is known that when PMMA microplastics enter the stomach, they cause a variety of health effects, including inflammation and cellular senescence.[17,19] On the other hand, if microplastics enter the lungs, it intensifies pneumonia along with other lung conditions due to the microplastics providing a surface for biofilms to grow.[4] This research is especially concerning because the proximity of the microplastics from dental products to our digestive and respiratory systems allows for the direct inhalation and digestion of microplastics. Further, the flexible and transparent qualities of plastic mean that its use in the medical field is predicted to increase worldwide.[20]

This review is one of the first literature review papers that compiles information regarding possible health effects of PMMAs and other dental microplastics that can be absorbed by the human body, focusing on the digestive and respiratory systems. Other papers focused on the source of dental microplastics and their possible environmental concerns. High-impact research was analyzed on what microplastics are produced by the dental field and the potential health effects caused by plastics commonly used in dentistry. By helping scientists, dentists, and the general public learn more about microplastic use in dentistry and how oral health products made of plastic can affect us, the hope is that the information can help dentistry move towards a safer and more sustainable future, and also raise awareness regarding the increasing use of plastics in our world.

METHODS

Pubmed and Google Scholar were used to identify scientific articles. Search terms included key words such as “microplastics from dentistry,” “Microplastics in dentistry,” “PMMA microplastic health effect,” “microplastic inhalation dental,” “polymethyl methacrylate health effects respiratory,” “polymethyl methacrylate respiratory,” “dental nanoparticle respiratory,” “microplastics how they enter.” PubMed was searched with the filters of “Free Full Text” and “Full Text” to focus on publically available articles. Sources that related to plastic in general or other organ systems not covered by this paper were excluded from the search.

Results

Author & Year	Type of Microplastic	Source of Exposure	Experimental Model	Major Findings	Key Limitations
Wu et al. (2025)	PE	Dental Calculus (Oral)	*In Vitro*	High mp concentration = reduced cell viability rate, increased apoptosis rate, reduced migration area, and increased ROS levels, leading to a higher inflamatory response in gingival fibroblasts.	Small sample size of 5 patients, cultured cells, short term
Li et al. (2024)	PMMA	Gastrointestional Tract	*In Vitro (Human) In Vivo (Mice)*	PMMA in human cell nuclei, increased ROS levels DNA damage and cellular senescence and inflamation in mice stomach cells.	Uniform 50nm microplastics from biotech company, cultured cells, short term
Boran et al. (2024)	PMMA	Absorption	*In Vitro*	PMMA causes oxidative stress, inflamation, and disrupted lipid metabolism in THP-1 and HepG2 cells	cultured cells, short term
Wang et al. (2020)	PMMA	Inhalation	*In Vitro*	PMMA increreased LDH and ROS levels, decreased macrophage cell viability	cultured cells, short term
Ma et al. (2025)	PE, PMMA	Inhalation	Observation	Microplastics helped MPP biofilms adhere, increasing risk of inflamation	short term

Table 1. Summary Table. Summary of Key Findings of Reviewed Studies.

The Digestive System

Recent studies demonstrate that microplastics have negative impacts on the digestive system.[17,21,22] In one study, the authors looked to find the potential health effects of polyethylene (PE) microplastics on human gingival fibroblast cells.[22] For their first procedure, the authors collected dental calculus from five adult patients with no prior history of dentures, and the calculus samples were sent to a lab for laser direct infrared imaging system analysis to determine the microplastic content of the calculus. It was determined that one of the highest percentages of the microplastics found was PE at 32.7% (Figure 1).[22] Next, the authors purchased uniform spherical PE microplastics of 80 nm size, and 7.5–30 μg/mL of the microplastics were added to cultured gingival tissues extracted from patients with impacted teeth. As expected, a positive correlation was found between higher PE concentrations and higher microplastic uptake. High microplastic uptake resulted in a reduced cell viability rate, an increased apoptosis rate, a reduced migration area, increased ROS levels, and a higher inflammatory response. Altogether, the researchers found that PE micro- and nanoplastics were present in the human oral cavity, and could contribute to symptoms that were observed, such as inflammation in gingival fibroblasts.[22–24] These findings are important because PE is one of the most commonly detected microplastics in toothpaste, highlighting negative health concerns resulting from daily dental hygiene routines.[7]

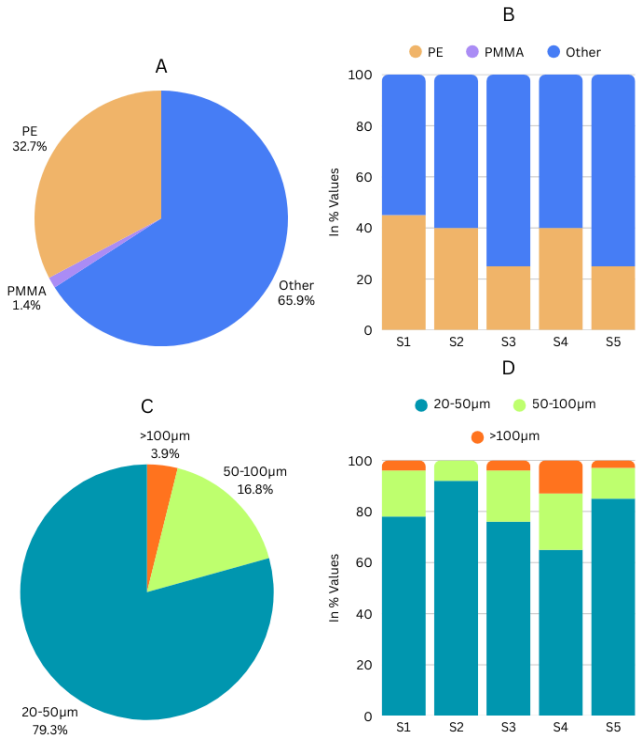

Figure 1. Micro- and nanoplastic composition in human dental calculus. PE was identified as one of the most common microplastics in dental calculus, with PMMA also being detectable in a small amount. The majority of the microplastics detected were in the higher size range of 20-50 μm. (A) The microplastic composition of the five samples as a whole. (B.) Microplastic composition of each of the five samples, shown individually. (C.) Microplastic particle size in the five samples as a whole. (D.) The microplastic particle size in the five samples is shown individually. PE, polyethylene; PMMA, polymethyl methacrylate. Figure and caption adapted from.22

In another study, the authors investigated the potential health effects of PMMA microplastics on aging gastric epithelial cells.[17] They focused on gastric epithelial cells specifically because the gastrointestinal tract is a prominent place for microplastic exposure. In their experiment, the authors purchased 50 nm PMMA microplastic particles, which are easily ingestible due to their small size, and added them to cultured kidney and stomach cells. The authors analyzed the impact of PMMA on the human tissue samples using a variety of methods, such as visual analysis using a microscope and fluorescence microscopy, where the authors discovered the presence of PMMA within the cell nucleus. In addition, they performed hematoxylin and eosin staining on the gastrointestinal tissues of mice after the mice were gavaged with PMMA particles to observe inflammation in the cells. Due to increased ROS levels, DNA damage, and the β-galactoside staining analysis, the study found that cell exposure to PMMA leads to cellular senescence and inflammation in mice stomach cells (Figure 2).[17] These findings are important because PMMA is found in dental aligners. Due to proximity, swallowed microplastics enter the stomach, which can contribute to impaired cell function.

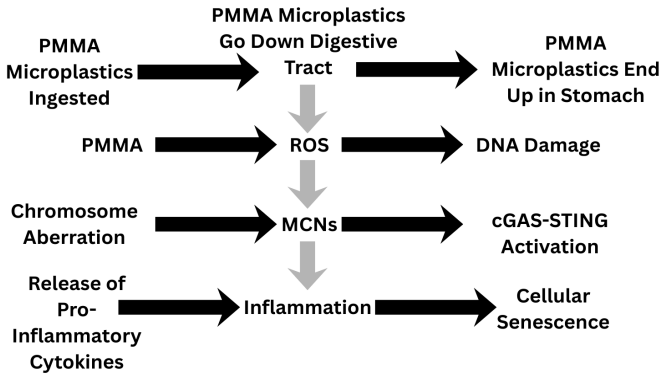

Figure 2. Diagram of PMMA's Health Effects on the Digestive Tract. After being ingested, PMMA was found to cause cellular senescence. This diagram shows how PMMA enters the digestive tract through methods such as dental restorative procedures. The PMMA travels down the tract where they end up in the stomach. The PMMA microplastic triggers the production of ROS, causing DNA damage, leading to chromosome aberration and micronuclei generation. Eventually, these steps lead to the activation of the cGAS-STING signaling pathway, which monitors genomic instability. Then, this leads to the release of pro-inflammatory cytokines, leading to inflammation. Ultimately, these factors contribute to cellular senescence. Figure and caption adapted from.[17]

To clarify the hepatotoxic effects on the human liver caused by PMMA microplastics, the authors used a co-culture model with THP-1 and HepG2 cells, where both were exposed to PMMA microplastics.[21] HepG2 cells are liver cells used to model the liver, and THP-1 macrophages are immune system cells modeling the immune response to PMMA, detecting if inflammation has occurred. By analyzing ROS production, inflammation, and lipid accumulation, PMMA was determined to be hepatotoxic to the liver. For example, the cell vitality of HepG2 cells and THP-1 macrophages decreased in both the mono-cultured and co-cultured models when PMMA concentrations were increased (Figure 3).[21] When PMMA concentrations were increased, an increase of ROS, a decrease in the antioxidant reduced glutathione, an increase of pro-inflammatory cytokines, and an increase in lipid accumulation were recorded, suggesting that PMMA also caused oxidative stress, inflammation, and disrupted lipid metabolism.[21] Ultimately, the inflammatory response caused by PMMA highlights the potential dangers posed by PMMA use in dental materials, and reinforces the necessity of developing dental plastics that don't shed toxic microparticles, plant based plastics, or even new biocompatible materials.

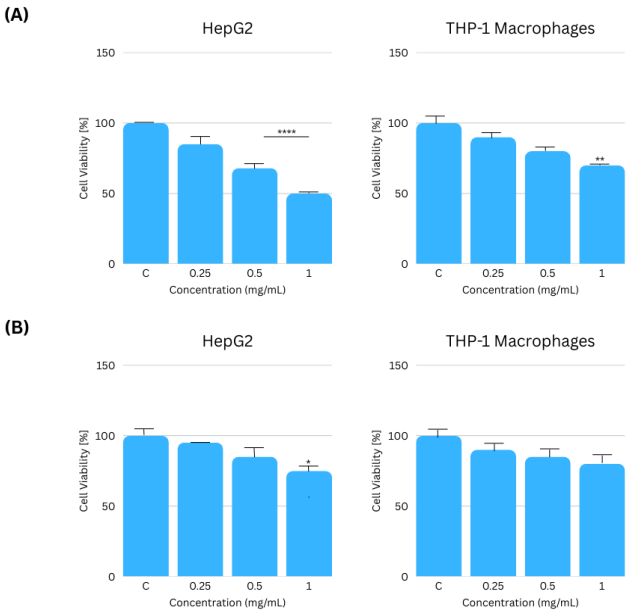

Figure 3. PMMA exposure's impact on mono-cultured (A) and co-cultured (B) system cell viability. PMMA microplastic exposure correlated with declining macrophage cell viability. (A) The cell vitality of HepG2 cells and THP-1 macrophages decreased with increased PMMA concentration. (B) The cell vitality of HepG2 and THP-1 macrophages also decreased with increased PMMA concentration. The concentration of PMMA is listed across the x-axis, and the percentage of cell viability after 72 hours is listed on the y-axis. Three replicates were averaged for each PMMA concentration, with error bars calculated based on standard deviation from the average. *$p < 0.05$, **$p < 0.01$ and ****$p < 0.0001$ vs control group. Figure and caption adapted from.[21]

The Respiratory System

Microplastic inhalation of airborne dental particulates results in respiratory toxicity.[3] Recent studies found that microplastics have a negative impact on the respiratory system.[4,25,26] In one study, the authors aimed to evaluate the possible health conditions caused by various types of dental prosthesis grinding dust on RAW264.7 macrophage cells.[25] This commonly used macrophage cell line was used due to its role as the immune cells present in the lungs, and the authors used these mouse macrophages instead of human macrophages due to availability and ethical concerns. In dentistry, grinding down materials is necessary for many operations, including prostheses making, orthodontic procedures, and restorative interventions. To determine the health effects caused by specific particles produced as a result of these procedures, the authors utilized PMMA, Vitallium, and porcelain dust particles. Out of these three materials tested, only PMMA was a microplastic. Dust particles for each material were added to cultured macrophage cells, and the effects of the dust particles on the macrophages were determined by analyzing changes to the shape of the cells and measuring the lactate dehydrogenase and ROS concentrations. The amount of LDH and ROS increased when concentration and time were increased. The authors discovered that porcelain had the most negatively impacted cell viability at around 20% at 48 hours, followed by PMMA and Vitallium, with around 55% and 50% cell viability at 48 hours, respectively (Figure 4).[25] The control also maintained 100% viability throughout the experiment. The dangers posed by PMMA microparticles from dental grinding dust highlight the potential risks both patients and dentists face when prosthesis grinding is performed.

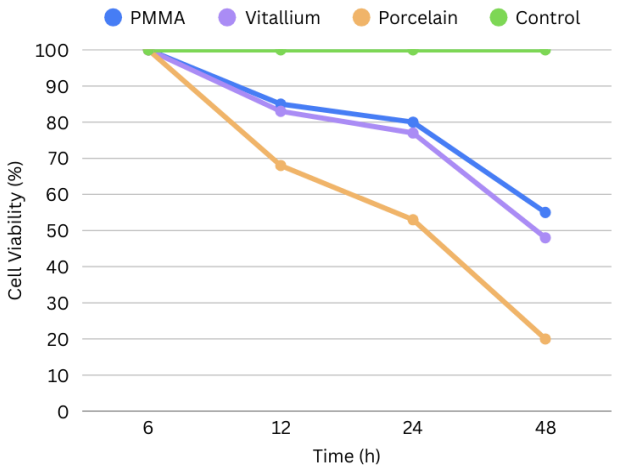

Figure 4. Different Dental Prosthesis Grinding Dust on Cell Viability of RAW264.7 Cells. While PMMA dental prosthesis grinding dust didn't decrease cell viability as much as its Vitallium and porcelain counterparts, PMMA still caused a decrease in RAW264.7 cell viability. Each sample type had 10 grams of the dust material. Cell viability decreased over time, with porcelain declining the most rapidly. Figure and caption adapted from.[25]

In another study, the authors sought to find a relationship between microplastic exposure and fluid in the lungs in patients with pneumonia.[4] The authors collected bronchoalveolar lavage fluid from children diagnosed with *Mycoplasma pneumoniae pneumonia* (MPP) infection. Pyrolysis, gas chromatography, and mass spectrometry were used to separate the microplastics from the fluid, leading to the differentiation of different types of microplastics. Many types of microplastics were observed, including PE and PMMA (Figure 5).[4] Microplastic concentrations in the fluid were compared with macrolide resistance, which revealed that exposure to microplastics increased the risk for MPP due to the correlation between increased microplastics and macrolide resistance.[4] The study found that the microplastics helped the *Mycoplasma pneumoniae* biofilms to adhere, which increased the risk of inflammation. The authors noted that PE microplastics were shown to have up to 7-19 times higher amount of microplastics compared to natural materials.[4]Therefore, steps should be taken to reduce the exposure to airborne microplastic particles in the dental field, as their presence has been shown to promote the growth of biofilms.

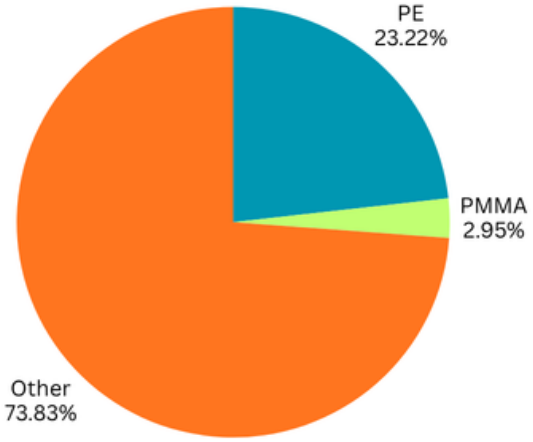

Figure 5. Microplastic composition of PE, PMMA, and others in Bronchoalveolar Lavage Fluid (BALF). PE was found in a sizable amount in BALF while PMMA was also found in a non-negligible amount. This diagram shows the microplastic composition in BALF. Shows the average concentrations of PE, PMMA, and other microplastics in all samples. PE at 23.22%, PMMA at 2.95%, with other microplastic compositions adding up to 73.83%. Figure and caption adapted from.[4]

DISCUSSION/CONCLUSION

Dental microplastics, such as PE and PMMA, were found to have negative health effects on the human digestive and respiratory systems. In the oral and gastrointestinal tracts, PE microplastics in dental calculus, cause inflammation in gingival fibroblast cells, while PMMA causes inflammation in stomach cells.[17,22,27] PMMA microplastic dust has been found to also have toxic effects on mouse macrophage cells.[25] Microplastic exposure in children was found to increase the risk for MPP.[4]

While these studies present significant findings, their studies have some potentially significant limitations. In the study regarding the health effects of PE on human gingival fibroblast cells, a critical evaluation of the study reveals the limitation arising from its small sample size of five patients. A common pitfall of studies on humans is the small sample size, which does not accurately represent the entire population as a whole, and thus, a bigger sample size is needed. In the study about the Gastric Epithelial Cells, the microplastics the authors used were bought from a biotech company (50 nm). These uniform microplastics do not represent the microplastic particles in the real world. Similarly. In the study about THP-1 and HepG2 cells, the author's procedure was not conducted on a liver, but rather it was conducted on cultured cells. The authors themselves have noted this limitation and have emphasized that further research on live subjects is needed in order to accurately show how microplastics impact or come into contact with the liver, as opposed to cultured cells.[21] Corresponding with this trend, the authors of the dental grinding dust study used mouse macrophage cells rather than human macrophage cells. A limitation of the MPP in children study was that, due to the study being the first of its kind, these methods were new, leading to a lack of validation and reproduction by others. One important limitation which all of these studies have in common were their artificial conditions, leaving questions regarding how accurately these artificial conditions model real life conditions. For the future of this research, more *in vivo* studies on humans must be conducted in order to definitively know the effect of dental microplastics on human health, and more research should be conducted regarding the possible health effects dental microplastics could cause on other human organs. It is also a priority to conduct long-term tests on the effects of long-term microplastic exposure, first using *in vitro* cells before moving on to human test subjects. While studies demonstrate that polyethylene and polymethylmethacrylate microplastics can induce inflammatory responses and cellular stress in experimental models, further longitudinal human studies are required to determine the clinical significance of these findings, such as the implications for human health and life expectancy. We should observe patients undergoing their daily oral hygiene routines, monitoring them for long-term health effects caused by microplastic exposure and accumulation. We should also conduct autopsies on recently deceased human subjects to determine locations of significant microplastic exposure and accumulation, and how it influenced local and systemic cell function.

Although there has been an increase in studies on microplastics compared to previous decades, there are still significant gaps in the current literature. One significant gap is the lack of long-term research. Most, if not all, of the studies utilized in this paper were short-term studies. The scope was another limitation, as this paper focused only on the digestive and respiratory organs. In addition, only open-access literature sources were used for this review, leaving the possibility that relevant data on this topic were missed. Another common trend is that many of the papers used focused on a specific type of plastic, such as PMMA, leaving a gap in the understanding of how different microplastics interact with one another in the human body. There has also been a lack of studies on the effects of biofilms that form on the microplastics, such as the pneumonia bacteria harboring biofilms that formed on microplastic particles in the lungs.[4] Most importantly, there has been a lack of studies that encompass all three of these factors, leaving researchers with little information to determine the overall long-term health effects of different microplastics and their biofilms on the human body as a whole. In spite of the limitations in each of these

studies, the scientific consensus is that these microplastics cause negative health effects on the human body.[4,17,21,22,25] Studies that came to contradictory conclusions could not be found.

Ultimately, this literature review seeks to provide a better understanding of the potential health effects of dental microplastics on the human body, specifically on the digestive and respiratory systems. According to current research, microplastics produced by the dental field have inflammatory effects on the human body. Steps should be taken to minimize plastic use in the dental field. However, due to plastic's unique advantages, a viable alternative may be in the form of plant based plastics, or also a form of biocompatible plastic that doesn't produce as much microplastics. For example, some companies like GT Smiles have developed plant based plastic aligners to replace regular petroleum based plastics. For dental practitioners, P100 (or equivalent) respirators should be used to filter out airborne particulates, especially during procedures that necessitate the grinding of procedural materials. A suitable plastic alternative that is more biocompatible is needed. For example, it is possible to replace oral health products such as toothbrushes and floss with products made from bamboo and cotton, respectively. Instead of plastic aligners, one could choose to wear metal braces. Also, steps should be taken to find a way to make already existing biologically-derived plastics commercially viable. Ultimately, steps should be undertaken to spread awareness of our body's inflammatory responses to dental microplastics and how the microplastics' structure provides an excellent place for bacterial biofilms to develop. Moving forward, more precise research on the negative health effects and development of biocompatible materials is necessary to promote a safer, healthier environment for all.

ACKNOWLEDGEMENTS

The author thanks mentor Lauren Lucas, PhD, for her feedback and advice on this research paper.

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