Thesis

Microplastic in surgery

A scoping literature review on the possible impacts posed by microplastics introduced into the body in surgery

Submitted by

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Declaration of Academic Integrity

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Graz, 17.10.2024 Lorenz Kircher m.p.

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Lastly, I want to thank my professors who helped me prepare for the path that lies ahead.

Zusammenfassung

Einleitung: Mit steigender Produktion und Konsum von erdölbasierten Kunststoffen entstand das Problem, dass neue Abfallmaterialien in den Ressourcenfluss gelangen. Allein im Jahr 2022 wurden 400Mt Kunststoffe erzeugt und verwendet. Trotz erheblicher Bemühungen der letzten Jahre landen 80% der produzierten Kunststoffe immer noch auf Deponien oder direkt in der Umwelt. Da Kunststoffe kaum biologisch abbaubar sind, werden sie nur durch mechanische und chemische Kräfte zerkleinert und zersetzt, bis sie eine Größe von 5 mm oder weniger erreichen.
Sobald sie diese Größe erreicht haben, können Mikro- und Nanoplastikpartikel leicht mit der Biosphäre interagieren. Publikationen haben gezeigt, dass sich MNPs im Magen-Darm-Trakt und in den Lungen von Tieren ansammeln können, wo sie Reizungen, Entzündungen, Dysbiose und die Einführung anderer schädlicher Substanzen wie EDCs und Krankheitserreger verursachen können. Erreichen MNPs eine genügend kleine Größe, so können sie auch durch natürliche Barrieren in den Blutkreislauf gelangen, wo sie potenziell weitere Schäden in Organen wie der Leber, den Nieren oder den Arterienwänden verursachen können.

Methoden: Eine umfangreiche Literaturrecherche wurde durchgeführt, um den aktuellen Stand der Wissenschaft über „Mikroplastik in der Chirurgie“ abzuschätzen. Die PRISMA-Richtlinien für wissenschaftliche Reviews wurden befolgt. Web of Science und PubMed wurden mit booleschen Begriffen durchsucht. Nach dem Screening von Titeln und Abstracts wurden vierzehn Studien im Volltext analysiert, fünf wurden akzeptiert und in dieser Arbeit diskutiert.

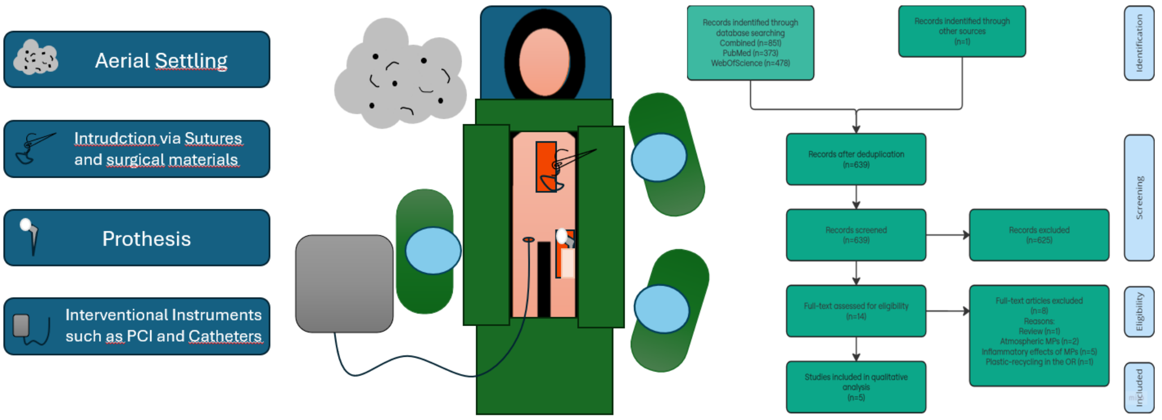
Ergebnisse: Zwei der Studien waren reine Laborstudien, drei waren Fallstudien an Patienten und Patientinnen, die sich chirurgischen Eingriffen unterzogen. In allen fünf Studien wurde Mikro- und Nanoplastik als Verunreinigung in den analysierten Geweben nachgewiesen.
Bis jetzt wurden drei Hauptwege der Einführung von MNPs während Operationen identifiziert: Erstens durch das Absetzen von MNPs von modernen chirurgischen Instrumenten, wie Kathetern und Infusionsbesteck. Zweitens durch das Ablagern aus kontaminierter Luft. Als letztes als unbeabsichtigte Nebenwirkung nach Abrieb, Abbau

und Zersetzung von Prothesen oder anderen chirurgischen Materialien, wie beispielsweise Fäden, die absichtlich im Körper zurückgelassen wurden.

Je nach Art des Eingriffs wurden unterschiedliche MNPs identifiziert, wobei PET, PE, PA und PGA am häufigsten vorkamen, aber auch PP, PS, PVC, PU, PMMA, PTFE und andere konnten nachgewiesen werden.

Schlussfolgerung: Während vermehrt Augenmerk auf die Forschung zu den gesundheitlichen Auswirkungen von MNPs gelegt wird, konnten bisher nur sehr begrenzte Daten über das Vorkommen von MNPs in chirurgischen Umgebungen und deren potenzielle Auswirkungen auf Operationsergebnisse veröffentlicht werden. Weitere Forschung ist erforderlich, um mögliche negative Auswirkungen durch MNPs zu identifizieren.

Main pathways identified for MNP-introduction in surgery
– a scoping literature review



Abstract

Introduction: With the rising production and consumption of petroleum-based plastics came the problem of new waste-materials entering the flow of resources. In 2022 alone 400 Mt of plastics were added to the world economy. Despite significant efforts in the last few years, 80% of plastics still ends up in landfills or directly in the environment. While plastics are barely biodegradable, mechanical and chemical forces degrade and disintegrate them until they reach sizes of 5mm and less.

Once at that size Micro- and Nanoplastics can easily interact with the biosphere. Research indicates that MNPs can accumulate in the gastrointestinal tract and the lungs of animals, where they can cause irritation, inflammation, dysbiosis and the introduction of other harmful substances, such as EDCs and pathogens. Once small enough MNPs have been shown to be able to enter the bloodstream as well, potentially causing further damage in Organs of accumulation such as the liver, the kidneys or arterial walls.

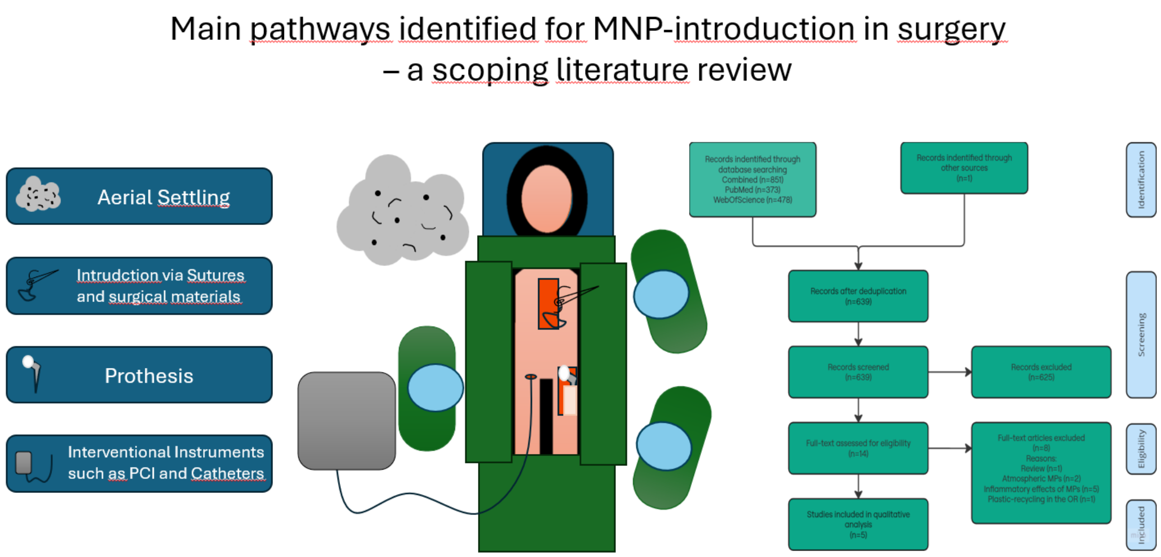
Methods: A scoping literature was performed to estimate the current understanding of modern scientific knowledge concerning “microplastics in surgery”. PRISMA guidelines were followed for scientific reviews. Web of Science and PubMed were searched with Boolean terms. After Title and Abstract-screening fourteen studies were full text analysed, five were accepted and discussed in this thesis.

Results: Two studies were purely laboratory studies, three were case studies in patients undergoing surgical procedures. In all five studies MNPs were found to be a contaminant in analysed tissue.

Preliminarily three major pathways of MNP introduction during surgery were identified: First, because MNP sheds of modern surgical instruments, such as catheters and i.v.-lines. Second, through settling from contaminated air. Lastly, as unintentional side effects after abrasion, degradation and disintegration of protheses or other surgical materials such as sutures left in the body intentionally.

Depending on the kind of intervention different MNPs were identified, PET, PE, PA and PGA were the most abundant, with PP, PS, PVC, PU, PMMA, PTFE and others also being identified.

Conclusion: While research into the health effects of MNPs is intensifying, very limited data has been published on the occurrence of MNPs in the surgical setting and their potential effects on surgical outcomes. More research is needed to identify potential negative outcomes caused by MNPs.



Previous Publications

No Publications to be declared

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List of abbreviations

BPA = bisphenol A

EDC = endocrine disrupting chemical

EU = European Union

EVA = ethylene-vinyl acetate

H2O2 = Hydrogen peroxide

HNO3 = Nitric acid

LDIR = laser directed infrared microscopy

MNP = Micro- and Nanoplastics

MP = Microplastics

NP = Nanoplastics

NaOH = Sodium hydroxide

PA = polyamide

PAH = polycyclic aromatic hydrocarbons

PAMPs = Pathogen associated molecular patterns

PC = Polycarbonate

PCI = percutaneous coronary intervention

PE = Polyethylene

PET = Polyethylene terephthalate

PGA = Polyglycolic acid

PLA = Polylactic acid

PMMA = polymethyl methacrylate

POPs = persistent organic polutant

PP = Polypropylene

PRISMA = Preferred Reporting Items for Systematic reviews and Meta-Analyses

PS = Polystyrene

PTFE = polytetrafluoroethylene

PU = Polyurethane

PVC = Polyvinyl chlorate

RCT = randomized controlled trial

SBF = Simulated body fluid

SEM = scanning electron microscopy

USA = United States of America

WWTP = Wastewater treatment plant

μFTIR = micro Fourier-transformed infrared microscopy

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1 Introduction

With the development of new and versatile materials made of organic compounds after the second world war, an increase in production capability and the invention of new technologies, plastics quickly became one of the fundamental resources produced and used in the modern world. Their versatility, strength and malleability allow for their use in almost all imaginable circumstances, today they are found in every aspect of daily life as well as in the most extreme circumstances. Ranging from onetime-use food wrappings to parts of the latest space exploration vehicles each year more crude-oil is transformed into useful plastics and organo-polymer composites.(1)

In its latest report "plastics europe" estimates that in 2022 400 megatons (Mt) of plastics entered the world economy, with over 8300 Mt being produced between the end of the second world war until 2015.(2,3)

Of said 8300 Mt, 6300 have been deemed as waste until 2015, with almost 80% discarded into landfills or lost to the environment.(2)

As plastics are designed and desired for their stability and malleability one of their defining features is the almost non-existent decay in the biosphere. This poses on one hand a significant advantage over other materials while used in modern society, on the other hand it leads to their accumulation as non-biodegradable waste, with estimated persistence of up to thousands of years in the environment, depending on the type of plastic.(4)

While almost not biodegradable, plastics do experience stress and decay through physical and chemical influences. Effects of ultraviolet light, abrasion and leaching of chemicals does eventually lead to the degradation and disintegration of plastic products in the environment. Through this process of degradation eventually smaller and smaller particles are left in the environment, once they reach sizes of <5mm in diameter the literature talks of microplastics (MP), with nanoplastics (NP) being defined as having a diameter of less than 1µm.(4,5) As the both sizes are able to interact with the biological environment, most of the literature does not differentiate between them and just calls them micro- and nanoplastics (MNP).

For the most part the literature differentiates between primary and secondary MNPs. Primary MNPs consisting mostly of pellets either being used as an initial raw material for plastic production or of particles with are designed to be in the range of microplastics, for example in toothpastes as an abrasion material or as a carrier medium for drug delivery.(6,7) Secondary MNPs on the other hand stem from the degradation and abrasion of larger macroplastics such as polyethylene bottles, polyester in clothing or nylon strings.(7)

1.1 Different kinds of Microplastics

While the intrinsic properties of organic compounds allow for a near infinite amount of differing types of polymers and plastics, in 2008 75% of all produced and used plastics consisted of just seven different types, namely low- and high- density polyethylene (LDPE and HDPE respectively), polypropylene (PP), polyvinylchloride (PVC), polystyrene (PS), polyethylene terephthalate (PET) and polyurethane (PU).(7) This narrow band of plastics used in our industries also directly accounts for the particles found as pollutants in the environment, with smaller amounts of other widely used materials such as nylon and polyester strings being described as well.

1.2 Micro and Nanoplastics in the Environment

MNPs have been found in almost any taken sample from the sea, air or the soil we grow our crops in. While first found in the water, where, due to their suspension in the column, MNPs interaction with the biosphere is easily understandable, today more and more papers show that MNPs interaction with the biosphere already starts at their inception on land.

1.2.1 Microplastics in waterways

First described and defined in 2004 Microplastics could at that time already be found in the entire water column around the British Isles. In their Paper Thompson et al. even analysed frozen plankton from the 1960s where they already found most of the differing types of microplastics, yet to a much smaller extent.(8)

In their paper they already identified the most common and to this day the best studied compounds accounting for the largest majority of MNPs.(8)

While the first studies were mainly focused on the prevalence of MNPs in the worlds oceans it was quickly discovered that by now they can be found everywhere on earth, with studies detecting them in places like the polar regions, the Mariana trench and the Himalayas.(9–12)
Due to their origin MNPs and microplastic pollution is still concentrated around densely populated areas where highest levels of pollution have been found. Examples are the North Sea where studies in 2013 already have shown concentrations of up to 2000 particles per litre with averages of around 50-100/L.(13) Another study found concentrations of plastic pollution in the Mediterranean Sea to reach 423g km^{-2} on average, with the Mediterranean being one of the most important coastal regions in the world (containing 10% of the world costal population).(14)

Once introduced to the water column MNPs become part of the food chain, being filtered by bivalves, and eaten by plankton. This allows them to be accumulated in larger predatory species as they consume their smaller pray.(15) Eventually finding their way back to human society as fish accounts for approximately 17% of animal protein and 7% of total protein intake worldwide.(16)

Most studies trying to measure the amount and effects of micro and nanoplastics on the environment were conducted to understand their impact on marine ecosystems. The reasoning behind this was the apparent path of plastics and their waste products being transported by the water cycle through river systems and estuaries into the worlds oceans, where they are easily visible and stay directly suspended in the medium which acts as the host of marine life.

1.2.2 Microplastics in soil and on land

As modern agriculture started to take more nutrients out of topsoil used to grow food, ways to reintroduce them were found. One of the most important mechanisms is the reintroduction of biosolids. Biosolids is the term used for treated and cleared sludge from wastewater treatment plants.(17)

As production and use of plastics increased over the past decades, MNPs were also introduced in healthcare products such as toothpaste as an abrasion material, soaps and skincare products as exfoliants and multiple different ways in the makeup industry.(18,19) Similar to MNPs stemming from common household items are particles found on streets. These secondary MNPs originating from the degradation of larger plastic pieces through weathering enter the wastewater system through stormwater drainage. Most of these products eventually enter the wastewater stream and end up in wastewater treatment plants.(20)

This usage of MNPs in day-to-day life and the usage of biosolids as fertilizer is the perfect combination through which potentially harmful substances may be introduced into the nutrient cycle. As modern technology has not yet advanced far enough to completely filter such MNPs out of the system entirely, the choice is either to let said MNPs remain in the cleaned-up water and therefore let them enter the water cycle further downstream or filter them out together with the sludge intended for fertilization on crop fields.(20,21)

Today in areas like the EU and the United States around 50% of the entire sludge out of WWTPs is brought out into crop fields. Calculating for the amount of plastics produced a 2016 paper by Nizzetto et al.(22) using eurostad-data estimates an annual emission of 1270 to 2130 tons of MNPs per million inhabitants. It further estimates that per million inhabitants between 125-850 tons of MNPs reach crop soils each year.(22)

While the amount of pollution differs significantly, by now MNPs are ubiquitous in agriculturally used topsoil. With one study (23) showing the gradual accumulation of MNPs in the soil over the first ten years after the introduction of biosolids to the topsoil in Chile was allowed and instituted. The study showed a quadrupling of Particles from less than 1p $5g^{-1}$ to more than 4.5p $5g^{-1}$ on the mean, extreme outliers even reaching more than 10 times the initial amount.(23)

1.2.3 MNPs and air pollution

The third large pathway of human exposure to MNPs is the inhalation of particles in polluted air. The origin, composition and abundance of these suspended particles differs significantly between environments.

First described in the air in 2016 by Dris et al. (24) MNP concentrations were measured in the air around Paris. Particle fallout was measured in two different locations and an average calculated. Depending on surrounding activity and precipitation concentration reached from 2-355 particles m^{-2} day^{-1}. In the same study the authors extrapolated their numbers and concluded that Paris receives an annual fallout of such particles in the range of 3 to 10 tons.(24)

The following year the same authors published another study comparing the air between different indoor environments. They chose two apartments and an office building to compare differently used spaces. Overall, they found that around 67% of the indoor fibres were of natural origins, such as wool or cotton, and only 33% stemmed from plastic resources. Fallout was also observed in all three locations, reaching at times more than 10000 fibres per day and m^2. If compared to the previous study researching dust settlement outdoors, this number is staggering showing the potential contamination of indoor environments. The same study also showed that the concentration of fibres in the air rises exponentially with a diminishing size.(25)

If compared to other studies 2019s study by Allen et al.(26) showed outdoor location is almost irrelevant when it comes to MNP load in the air. At their study site in the Pyrenees they could find nearly the same amount of MNPs as Dris et al.(24,25) found in their previous studies in Paris. With similar amounts being reported in Hamburg and Dongguan, China.(27,28)

1.3 Micro and Nanoplastics as health risk in humans

Platics in general count as relatively biological inert materials. They have been used in various forms for almost 100 years and most of the time no severe effects on human health could be observed. Concern for plastic pollution was mostly kept to the effects of macroscopic pieces entering the environment and disrupting the food chain of bigger animals.

Only once it became clear that microplastics could engage in a different manner with the environment were new concerns regarding health and wellbeing raised.

1.4 Pathways of absorption

Just as with most other common pollutants in the environment three main pathways of exposure were determined. Ingestion and inhalation counting for most of the exposure, while dermal contact was described as another viable pathway.

1.4.1 Ingestion

One of the two main exposure pathways to microplastics described in daily life has been the ingestion of MNPs while eating, with studies such as Schwabl et al. (29) and Zhang et al. (30) showing conclusive evidence of MNPs in human feces.

As discussed earlier in the introduction MNPs have been found ubiquitous in the environment, especially in the marine ecosystem. Studies have shown the contamination of bivalves(31,32), fish(33), and other food products such as table salt (34) with MNPs, suggesting ingestion of microplastics in everyday life for almost all people living in the modern world. Depending on the study scientists estimate a MNP contamination of 0,04 to 2,4 MPs/g wet weight in mussels caught .(32)

But not only food of oceanic or other aquatic origins is proven to contain MNPs, differing studies have by now shown MNP contamination of milk(35,36), meat (chicken)(37) and potentially even cereals(38).
While studies like these paint a concerning picture of the state of global food chains, research in the true amount of contamination is still ongoing. The studies concerning milk have a fluctuation of concentrations of a factor of 10 between each other, and there has been no conclusive evidence of chicken and cereal contamination preprocessing. The lack of concrete evidence might be indicative that MNPs found in these foods could largely stem from packaging or handling of food products.

In similar studies it has been shown that a large percentage of ingested microplastics might stem from bottled beverages and water or other plastic packaging used in most modern supermarkets to keep food fresh for longer.(39,40) With Cox et al. proposing a potential doubling in intestinal MNP exposure per year in people who consume drinking water mainly in the form of bottled sources.(39)

Yet still more pathways of intestinal uptake of MNPs have been proposed, such as the consumption of MNP fallout on dinner plates during mealtimes or the swallowing of mucus produced by airways to clear MNP pollution out of the upper airway tract.(41)

Depending on the location, diet and lifestyle Senathiraja et al.(42) calculated an average intake of MNPs through ingestion per week and person of 0,1g - 5g. As put by Palanisami, one of the authors of the paper, this would equate to approximately one credit card a week per person.(42)

Once inside the gastrointestinal tract, MNPs have the potential to interact with the endogenous microbiome as well as the intestinal wall. While dysbiosis has been shown in multiple animal studies, conclusive evidence of microbial shifts in the human body are to date very limited.(43,44)
Most particles are restricted to the gastrointestinal tract, yet particles small enough, approximately 500nm and smaller, could eventually pass the mucosal lining and be absorbed into the bloodstream.(45)

While theories such as the described have been put forward, experimental studies have mostly been kept to in vitro or animal models. For every proposed mechanism of absorption into the bloodstream, a thorough rebuttal has been put forward. The only thing reviews and papers on this topic are sure to agree on at this moment, is the necessity for more studies and better ways to detect MNPs in the gut and the intestinal lining.(46,47)

1.4.2 Dermal absorption

Dermal absorption is most likely the least significant of the three described pathways.
Due to its main function as a protective barrier the skin is physiologically hard to cross for most substances, even in the µm range. Yet smaller particles could eventually break that barrier.

As described by Bos et al. Nanoparticles up to the size of 500 Dalton could potentially diffuse through the skin.(48) In later studies other authors painted a more complex picture as it became apparent that not only the size of the particle but also form, charge and factors like skin health, hair follicles and mechanical stress could also play significant roles in the accumulation of nanoparticles in the human body via dermal absorption.(49,50)

Today it is agreed in the literature that, particle absorption in healthy skin is largely limited to pores and glands surrounding hair follicles. Demonstrated by experiments showing hairless mammal skins taking up almost no MNPs.(49)

For fear of absorption of nano plastics via the skin most personal care products containing primary microbeads as abrasive material have been banned in the EU, USA and Canada in the mid-2010s.(51)

1.4.3 Inhalation

As established earlier in this thesis, MNPs can be found suspended in the air in virtually all environments.(25,26,28) Therefore the question is not if humans inhale MNPs, but rather how many and at what size do they reach relevant structures in the human lungs such as the alveoli where they can cause irritation and other problems, or may even be absorbed into the bloodstream.

Because the settling of particles depends so much on the aerodynamic shape, the aerodynamic equivalent diameter has been proposed to create comparability.(52) In general it can be said that, only particles of a diameter less than 5µm can be deposited in the alveoli. If it comes to fibres the diameter has to be even smaller with 3µm being the proposed upper limit of fibres reaching the alveoli. Length on the other hand does not seem to impact the deposition as much, with thin fibres reaching lengths of 30-40µm.(53)

First described in 1998 by Pauly et al.(54) inhalation of microplastic fibres is a virtual certainty in todays environment. While the route of ingestion has been thoroughly described in other studies, inhalation of MNPs as a way for pollutants has not yet been fully explored.(46,55)
There are studies like Pauly et al.(54) and Amato-Lournco et al.(56) that do show MNPs can easily be found in both healthy human lungs as well as tumorous lesions causing the need for lobectomies.

The small size necessary for particles to reach the alveoli also makes them especially suited for interaction with the biosphere. With diminishing size surface charge increases (57). This property strengthens MNPs ability to accumulate an eco-particle corona, leading to easier internalization.(58) At the same time does such an eco-corona enhance MNPs pathogenicity as toxic substances and pathogens can easier attach to the particle and be absorbed into the body with them.(59,60)

With MNPs being proven to be carriers for other substances such as lead and polycylic Aromatic Hydrocarbons (PAHs) as well as dyes and plasticizers other novel substances can reach the lungs through MNP inhalation as well.(61)

1.5 Potential toxicity

The potential toxicity of MNPs has yet to be determined to its full extend. Different mechanisms such as chronic inflammation, adsorption of pathogens, carrying of smaller soluble endocrine disrupting chemicals (EDCs) such as bisphenol-A (BPA) or phthalates or carcinogenicity have been proposed.

1.5.1 Damage to the intestinal lining

Upon reaching the gastrointestinal tract MNPs have been shown to have a host of differing effects on the endogenous microbiome. While studies in human participants have shown alterations in the microbiome, if more microplastic particles were found in feces, for ethical reasons prospective studies have been mostly limited to animal models.

With different studies showing dysbiosis(62,63), inhibition of assimilation(64,65), inflammation(66) and restructuring of the epithelium(67). While probably not too relevant to humans some studies found a reduced appetite, caloric intake and therefore diminished size in small animals due to a gastrointestinal tract filled with microplastics.(68)

1.5.2 Dysbiosis

Dysbiosis describes the imbalance of physiological bacterial colonies in the gut of individuals.(69) While it might not necessarily be the reason for certain diseases, it has been linked to a whole host of lifestyle diseases, such as metabolic syndrome(70) and IBS(71), but also diseases such as depression(72) and even cancer(73).

The effects of MNPs in causing dysbiosis might not fully be understood, but some significant pathways have been put forward. For one, MNPs might mechanically damage the intestinal lining, leading to a higher interaction between the hosts immune system and normally separated bacteria.(74,75). Another important pathway seems to be EDCs such as phthalates, often used as plasticisers, which, through their hormone imitating effect might alter the communication pathway between hosts and their microbiome, resulting in dysbiosis.(76,77)

1.5.3 EDCs and Pathogen carrier

EDCs being released from MNPs does not only have the potential to harm the microbiome in the gut, but could potentially be absorbed by animals who ingested said MNPs, resulting in MNPS severely changing an animals hormonal equilibrium and therefore effecting their health. One of the best examples of this is BPA(78), yet other chemicals such as polycyclic aromatic hydrocarbons (PAHs) and polychlorinated butenyls have been observed. (79,80)

Due to their size, shape and surface MNPs have been indicted for acting as carriers for potentially harmful bacteria. Like most other plastics, MNPs provide the ideal surfaces for a biofilm to form. With Vibrio species having been identified on MNPs(60,81) their ingestion may lead to dysbiosis, increased intestinal permeability, and endotoxemia (82).

1.5.4 Oxidative Stress and Cytotoxicity

Nanoparticles with a high surface area can induce oxidative stress, cytotoxicity, and translocation to other tissues, potentially resulting in chronic inflammation and an increased risk of cancer. Oxidative stress may arise due to the large surface area of the particles, the presence of metals on their surface, or as part of the inflammatory response. Cytotoxicity on the other hand can occur through internalization, allowing nanoparticles to interact directly with cell organelles, or through the release of reactive oxygen species (ROS) by the body (83). Additionally, macrophages in the lungs may experience protein misfolding and ROS release (84).

1.5.5 Effects on Energy Homeostasis

MNPs may affect energy homeostasis, potentially by regulating digestive enzyme activities (85). As inflammatory responses result in higher energy consumption (86) exposure to MNPs could lead to an increase in lactate dehydrogenase (LDH) activity (66,85). Additionally, MNPs might disrupt lipid metabolism by influencing the expression of RNA related to peroxisome proliferator-activated receptors, leading to reduced energy mobilization(87).

1.5.6 Translocation

The translocation of nanoparticles through the intestine and lungs has been observed since the early 1990s (88,89). Once in the bloodstream, PS microbeads have been linked to pulmonary hypertension, vascular occlusion, and increased coagulation in rats(90–92) In vitro studies suggest that PS induces the aggregation of red blood cells on endothelial surfaces (93). Nanoparticles can also accumulate in organs such as the liver, kidneys, and intestines, causing oxidative stress, neurotoxicity, and energy imbalances (66). Additionally, MNPs in bone tissue may contribute to bone loss and the activation of osteoclasts (94).

1.5.7 Disruption of the Immune System:

MNPs may trigger autoimmune activation on the same pathway as aerial particulates. These particles have previously been linked to systemic autoimmune rheumatic diseases(95) and systemic lupus erythematosus (96). Exposure to MNPs may also result in a decreased T-helper cell count (97) and potentially exert immunosuppressive effects (98).

1.5.8 Neurotoxicity

MNP-induced neurotoxicity may result from oxidative stress, the activation of microglia, or the production of proinflammatory cytokines (99). Increased exposure to particle pollution has been associated with a heightened risk of Alzheimer’s disease (100), suggesting similar mechanisms of action. In fish, MNPs have been shown to inhibit acetylcholinesterase activity (101), with the effect of raising levels of acetylcholine in synapses resulting in symptoms such as headaches, confusion and troubles with memory(102)

1.5.9 MNP-Induced Cancer

Long-term exposure to MNPs is strongly associated with cancer development (103). This risk arises through mechanisms such as chronic inflammation and DNA damage (104).

Exposure to MNPs has been linked to an increased risk of stomach cancer (105). BPA has been shown to promote cancer growth by binding to and activating the oestrogen receptor beta (106). Additionally, BPA may promote cancer cell cycles by upregulating the pituitary tumour-transforming gene 1 (PTTG1) (107).

With plastics being such a diverse group of materials, their potential negative health effects are equally diverse and complex. While some examples of possible and definite dangers of MNPs have been presented here, listing them all would far overshoot the scope of this thesis. Therefore, only some of the most prevalent topics have been chosen. One also must keep in mind that not every kind of MNP causes all of the listed effects but rather each cause some or another.

2 Microplastic in surgery

2.1 A scoping literature review to gain an understanding on the existing literature on MNPs in surgery

With the term “Microplastics” being defined in the Thompson et al. (8) for the first time, a new field of study has opened up. The scientific community quickly started to gather data on the existence and distribution of MNPs in the environment.

Soon after the first papers were published concerning the question of human health being affected by said MNPs. These studies focused for the most part on the effects of particles inhaled, ingested and absorbed via the skin. As alluded to earlier in this thesis a few have discussed finding MNPs in tissue not directly in contact with the external world (such as in the liver, the blood and atherosclerotic tissue). This appearance in tissues not in contact with the external world imposes the question, whether there might be new and different pathways of MNP introduction into the human body and what their potential effects are.

As the author of this thesis is not aware of any studies concerning potential contamination of operating theatres with MNPs a scoping literature review is deemed necessary to establish the basis for potential further studies and their design.

As MNP contamination of the atmosphere, especially in closed environments has firmly been proven, a null hypothesis was posed:

The literature shows operating theatres to be contaminated with MNPs.

With the alternative hypothesis being defined as:

No studies concerning possible MNP contamination in modern operating theatres exist in the current literature

If the null hypothesis is to be discarded and the alternative to be accepted, a clear charge to conduct further research will be established.

On the condition that the null hypothesis must be kept, another question will arise:

Is there any evidence, this contamination of operating theatres and surgical sites negatively impacts patients' health?

For this second question the null hypothesis will be:

> *The scientific evidence supports the notion that MNPs negatively affect patients' health in surgical settings*

With the corresponding alternative hypothesis:

> *No such scientific evidence exists*

3 Methods

As this was to be scoping review of the existing literature no approval by an ethics committee was deemed necessary.

3.1 Literature search strategy

The Literature search was performed on the platforms PubMed Central and Medline as well as through Web of Science.

In order to obtain the most amount of relevant articles, without losing too much specificity Boolean search terms with the operators AND and OR were chosen. The resulting query for PubMed was decided on:

("surgery" OR "surgical" OR "operation" OR "operative" OR "surgical procedure" OR "invasive procedure" OR "surgical intervention" OR "medical operation" OR "surgical treatment" OR "operating theatre" OR "operating room" OR "operating suite" OR "surgical environment")

AND

("microplastics" OR "plastic particles" OR "plastic pollution" OR "micro-debris" OR "nano-plastics" OR "plastic fragments" OR "microplastic fibers" OR "plastic waste" OR "microplastic pollution" OR "microplastic contamination")

For the query in Web of Science the Terms were modified to fit its advanced topic search. Resulting in the following term:

TS=("surgery" OR "surgical" OR "operation" OR "operative" OR "surgical procedure" OR "invasive procedure" OR "surgical intervention" OR "medical operation" OR "surgical treatment" OR "operating theatre" OR "operating room" OR "operating suite" OR "surgical environment")

AND

TS=("microplastics" OR "plastic particles" OR "plastic pollution" OR "micro-debris" OR "nano-plastics" OR "plastic fragments" OR "microplastic fibers" OR "plastic waste" OR "microplastic pollution" OR "microplastic contamination")

English was chosen as the only language of considered articles.
As the term “Microplastics” was first coined in 2004 by Thompson et al. in their landmark paper “Lost at Sea: Where Is All the Plastic”, the search window was kept to the timeframe between 2004 and 2024.

3.2 Eligibility criteria

In this review only studies trying to establish a causal link between surgery or similar surgical interventions and elevated levels of micro- or nano- plastics in or around the patient were included.
Due to the combination of the very limited amount of existing literature and a research question merging the subjects of environmental microplastics in the surgical setting and patients’ health outcomes, all kinds of studies, from purely laboratory settings to RCTs were deemed eligible to be included in this scoping review.

3.3 Study Retrieval and Selection for Analysis

Studies were first screened by title, in the next step Abstracts were screened as well. Of the 12 studies deemed eligible in the Title and Abstract screening, full text versions were retrieved and analysed.
Only five of the 12 studies were included in further analysed with data extraction and compounding of results.

3.4 Analysis of eligible Papers

Due to the heterogeneity of recovered studies, only a qualitative analysis of retrieved papers would be possible. Data from differing papers will not be synthesized and no statistical analysis of the retrieved will not be possible.

4 Results

4.1 Study retrieval and Characteristics

The literature search was conducted according to the PRISMA guidelines for systematic reviews and meta-analyses. As shown in the Flowchart of the study retrieval process, 373 papers were identified through *PubMed*, with another 478 papers being found on *Web of Science.* One extra study was identified outside the original search query, it was found as a citation to one of the other four eligible papers. After deduplication 639 studies remained, which were screened first by title and afterwards by abstract. Resulting in a list of 14 studies eligible for full text evaluation. Only five of these papers could be included in the analysis. The other nine studies had to be discarded as well. One as it was a review of MP pollution in the atmosphere, two for only microplastics in the atmosphere, but not in hospital and surgical settings. One more for studying the possibility of reducing plastic pollution through surgeries and therefore contributing to a circular economy. The rest because the topic of their studies stuck to the exploration of effects of microplastics in the human body, without studying the path of introduction into the body at all.

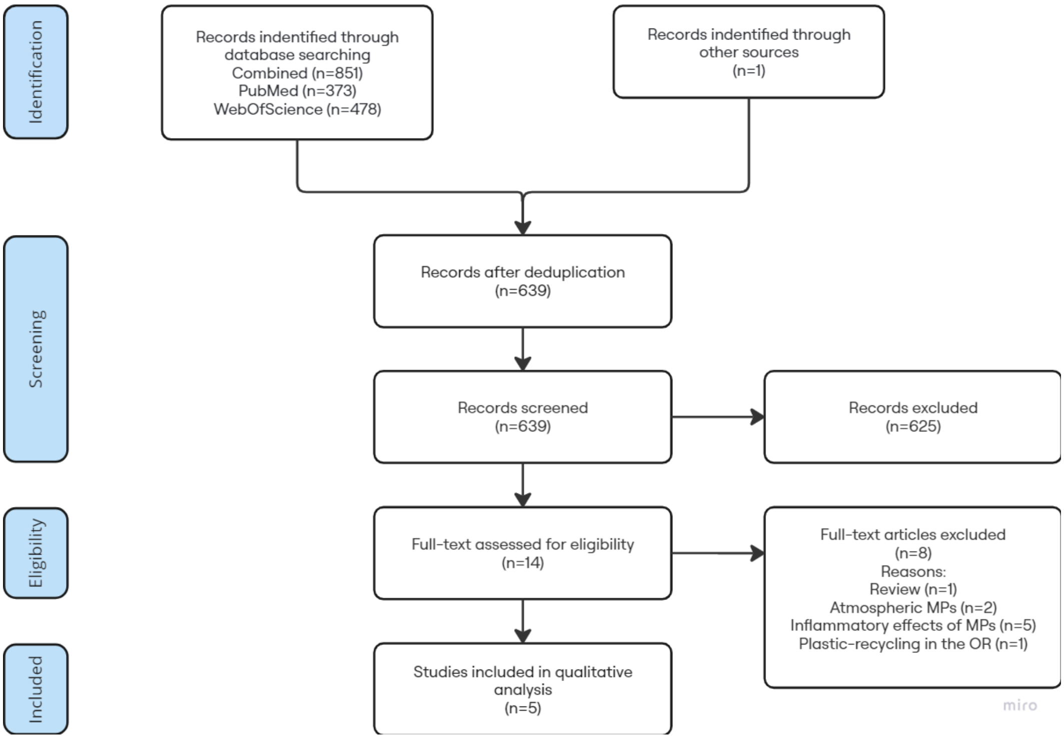

Figure 1 PRISMA flowchart for literature retrieval and study selection process, microplastics and surgery

The five analysed papers included, one study proving the formation of micro and nano plastics in the process of absorbable suture degeneration in simulated body fluid.(108) Two focused on the introduction of MNPs into the blood stream as a result of major intervention such as PCI(109) or cardiac surgery(110). The second to last paper described the air pollution by microplastics in surgical theatres published 2022(111) and the last one found as a citation to Shi et al. (108) researched the abrasion of PE in total knee arthroplasties in 2003(112).

4.2 Studies accepted for inclusion in Analysis

After the Full text screening four studies were initially accepted for analysis. Upon analysis, another potential study was found as a citation in Shi et al.(108), it was screened included in the analysis. As the study by Minoda et al. (112) was published in 2003 and focused singularly on the existence of PE MNPs it was not found in the initial query.

Author	Year	Location	Most abundant MP	MPs found	Amount of MNPs found	Size Range analysed	Mean or mode particle size	Pore size	Chemical Digestion	microscopy
Shi et al.	2024	Laboratory SBF	PGA	PGA, polyglactin 910, poliglecaprone 25	0.63±0.087 million per cm	0-1000nm	mode, <50nm, 72%	0.05µm	no	SEM
Field et al.	2021	Surgery room	PET	PET, PP, PE, Nylon, PTFE, EVA, PVA, PA, PP-PE-Co	3367±2970 per m^2d	10-1000µm	mean, 92±136µm	0.2µm	no	µFTIR
Yang et al.	2023	In patient Cardiac surgery Heart tissue and blood	PET	PET, PE, PC, PU, PP, PS, PA, PVC, PMMA	not given	20-469µm	mode, 20-30µm, ~ 40%	1µm	yes	LDIR
Liu et al.	2024	In patient PCI blood	PA	PA, PE, PU, PET, PP, PS, PVC, PC, EVA, ACR, PMMA, PTFE	93.57±35.95 per 10ml of blood	20-212µm	mean, 35.29±22.68µm	10µm	yes	LDIR + SEM
Minoda et al.	2003	In patient TKA Synovial fluid	PE	PE	1.23±0.62 x 10^7/ml	<0.2->3µm	mean, 0.78±0.08µm	0.2µm	yes	SEM

Figure 2 Table comparing plastics, size, abundance and microscopy

4.2.1 “Microplastics in the surgical environment” by Field et al.

Realizing the mounting evidence of growing air pollution by MNPs Daniel T. Field et al. posed the question whether this has significant impact on the surgical environment. The ascribed goal of their study was to analyse the abundance of MPs in the operating room as well as its adjacent anaesthetic room, to examine the profile, shape and size of said MPs, stipulate their origin and to compare their abundance in times of use and in non-working hours. The study was conducted in 2022 in the United Kingdom, with probes being taken in Castle Hill hospital, Cottingham and analysed at University of Hull, Kingston upon Hull.(111)

Samples were collected in beakers, cleaned and prepared in a previously described fashion by Jenner et al.(113,114). The beakers were then put on top of the anaesthetic machine in the operating theatre. They were swapped every 12 hours at 8am and 8pm respectively, to achieve differentiation of working and non-working hours. This continued for seven days with 14 samples being taken over the study period. In the adjoining anaesthesia room, the same procedure was carried out for another 14 samples.(111)

Afterwards the taken samples were processed in bulk, they were rinsed with pre-filtered and distilled water. The water containing the samples was then passed through an Anodisc filter with a pore size of 0.2µm. The same procedure was repeated two more times to be able to collect all available samples. After a drying period of 24 hours the filter was analysed using micro- Fourier-transform infrared spectroscopy (µFTIR).(111)

Assuming even distribution a quarter of the filter was analysed for the amount of MPs present. The rest was then studied for size and form. The resulting spectra were then compared to a previously established database (Omnic polymer library). Per particle three attempts were made to identify a match. Only overlays of more than 70% were counted.
The results were then extrapolated and converted to m^{-2} d^{-1} (factor of 105.2264 to adjust for the area studied and factor of two for the twelve hours of sample taking per beaker). To be able to calculate the statistical amount of contamination in the two rooms SPSS was

used. After a Shapiro-Wilk test showed no normal distribution of particles, a Mann-Whitney-U test was applied.(111)

With almost no contamination on the control filters studied, no correction of the results was carried out.(111)

Upon analysis it was shown that particle fallout comprised mostly of matter not of plastic origin. Here they could show a mean fallout in the operating theatre of 37,882 ± 15,950 m^{-2} d^{-1} during working hours, with significantly reduced fallout during the night. Overall, 89% of particle fallout in the operating room did not stem from plastic sources. As pertaining to the particles classified as MNPs during working hours Field et al. found a fallout of 5388 ± 2,830 particles m^{-2} d^{-1} with a statistical p value of 0.00047 as to the difference between working and non-working hours. This infers on the opposite side, 11% of dust in operating rooms may stem from synthetic materials.
While the amount of MNPs in the anaesthesia room was lower as compared to the operating theatre, they couldn't prove significance between the rooms. Like in the operating theatre they could show significantly less MNPs during non-working hours.(111)

As to the composition of the plastic particles contained in the fallout of the surgical environment, the authors found that like in other studies performed outside the hospital environment the smaller the particle the more abundant it is.(111)

Most of the particles were classified as fragments (78%) with fibres (20%) and spheres (2%) constituting the rest.(111)

Similar to other studies (110) the largest amount of synthetic particles stemmed from PET (37%), with PP (25%), Nylon (13%), PE (7%), PTFE (5%) and EVA (5%) accounting for most of the rest.(111)

4.2.2 “Detection of various microplastics in patients undergoing cardiac surgery” by Yang et al.

In their 2023 paper Yang et al., described in a case series in Bejing China the discovery of MPs in patients undergoing cardiac surgery. Their incentive was to study the occurrence of MPs in organs and their tissues not in direct contact to the external environment. For this they took samples from 15 patients’ epicardium, myocardium, left atrial appendage, the pericardial adipose tissue and epicardial adipose tissue. As a quality control for their sampling, Yang et al. took blood samples of willing participants (n=7) before and after surgery.(110)

To minimize for aerial contamination, blanks were shortly opened in the surgical environment to simulate sample taking and achieve the ability to counteract any potential distortion. All samples were digested by the same procedure. First 30 wt% H_2O_2 was added to the container, after 20 days HNO_3 and NaOH were added to the samples to achieve full digestion.(110)

Once fully digested samples were analysed with the help of laser direct infrared (LDIR). The cut off for a match was set to 80%. The analysed range of particle size was 20-500µm. owing to limitations of filters at the lower end and the expectation of an upper size limit of approximately 150-200µm for MNPs ability to enter the body, as proposed in Barboza et al.(101). Any discovered matches were afterwards further analysed using scanning electron microscopy.(110)

Resulting Yang et al. could describe MPs in in every kind of tissue. PET accounted for 77%, PU for 12%. The only material found in all different kinds of tissue was PE accounting for less than 1%. The rest of the MNPs were identified as PC, PP, PS, PA, PVC and PMMA, accounting for approximately 10% all together.
Overall, the distribution of MNPs both in number and kind differed widely among patients and tissues, with one patient contributing all the PC particles, and 75% of PET particles.(110)

The blood samples taken in surgery showed significant variability with MNPs in the size range of 20 to 184µm. Importantly Yang et al. showed that the composition of MNPs changed significantly from before to after surgery. While PET was the predominant type of MNP before surgical intervention, PA was the most abundant after intervention. In addition, they could also observe a significant change in the size of the particles found in patients' blood after surgery, interestingly in this study they found a diminishing size as compared to Liu et al. (109,110)

4.2.3 "Percutaneous coronary intervention leads to microplastics entering the blood: Interventional devices are a major source" by Liu et al.

In the same hospital as Yang et al.(110) Liu et al. showed that PCI introduces MNPs into the human circulatory system.
For their study blood was drawn from 23 patients undergoing PCI before and after their intervention. In addition, eight patients had another sample taken 2, 4, 8 and 12h post intervention.(109)

Samples were digested in HNO_3 for 48h at room temperature. Before being filtered through stainless steel filters with a pore size of 10µm. The filters were then washed in ethanol to retrieve the samples. The ethanol containing the MNPs was then reduced to 200µl for analysis.(109)

As in the previous studies extensive care was taken to minimize the risk of post sampling contamination with researchers wearing nitrile gloves and cotton lab coats. The samples were handled in a non-ventilated bench to reduce areal contamination. In addition, tests for recovery percentages were performed. And blanks were handled in the same ways as sample probes to account for background contamination. As they did not detect any contamination in their blank controls no adjustment was deemed necessary, data was directly analysed without correction.(109)

Results were tested for normal distribution and where applicable presented as mean ± standard deviation. If no normal distribution was found, results were displayed as median (25^{th} – 75^{th} percentile). As in most studies SPSS was used for the statistical analysis.(109)

In their analysis Liu et al. found MNPs in 22 of the 23 samples taken pre intervention, while all patients had MNPSs found in their circulatory system post intervention. Overall, they could show an overall increase from 4,96±3,4 particles /10ml blood to 93,57±35,95 particles/10ml blood ($p<0,001$). The biggest increase was seen in PA, from 1,22±0,95 to 63,52±28,06, with materials such as PE, PU, and PET also seeing significant increases in their concentration.(109)

In the eight patients who had more samples taken over the next 12 hours, elevated concentrations of MPs could be observed. Concentrations stabilized in this study at approximately 50±20 particles per 10ml blood, far above the concentration in samples taken pre-PCI.(109)

As a second experiment devices such as the angiographic guidewire, catheter and guiding catheter twice washed in purified water. Syringes and disposable Infusion sets were twice "used" to obtain samples from classical disposable medical devices. With this they could proof the origin of MPs introduced to the body in PCI, as the released particles consisted for the most part of PA, PE, PU and PET as well as PTFE, the same particles found elevated in patients' blood. While particles of materials used in the devices themselves did not significantly reduce between the two washings, materials used in the packaging only were significantly less common in the 2^{nd} washing.(109)

In comparison Liu et al. found that the particle size contained in blood pre-PCI was smaller to the sizes post-PCI, while particles found in the washout from instruments were larger still.(109)

4.2.4 “Micro and nano plastics release from a single absorbable suture into simulated body fluid” by Shi et al.

Absorbable sutures are a common staple of modern surgical techniques. To determine potential disadvantages Shi et al. conducted a laboratory study on the release of microplastics into body fluids by absorbable sutures.(108)

As in the other studies meticulous preparations were taken to ensure clean working conditions and reduce the risk of contamination. Therefore, the researchers wore particle free nitrile gloves, cotton lab coats and lab caps at all times. Blanks were used as base comparison to understand background noise.(108)

The simulated body fluid was prepared to the standard protocols, resulting in electrolyte concentrations similar to human plasma and a physiological pH-value.
In their experiment they compared three widely used absorbable sutures PGA, Vicryl (polyglactin 910, a compound made 90% of PGA) and Monocryl (poliglecaprone 25, made of 75% PGA) to non-absorbable ones such as PA and PP.(108)

Sutures were wrapped around a clean glass rod and placed in 100ml of the simulated body fluid (SBF) for a duration of eight weeks. During this time temperatures were kept to normal body temperature of 37°. In addition to the temperature the beakers were placed in a shaker put to 100rpm.(108)

After eight weeks samples were taken from all beakers and filtered through a gold-coated polycarbonate membrane filer with and average pore size of 0,8µm. The filters were then analysed first in Raman and afterwards in SEM. In addition, samples were passed through a 1µm filter and a 0,2µm filter to identify nano particles.(108)

Results showed a purely PGA based suture dissolving significantly faster then combined sutures. On average PGA, Vicryl and Monocryl released 630 000 MPs cm^{-1}, 37 000 MPs cm^{-1} and 11 000 MPs cm^{-1} within the 8-week window. If loaded, thus simulating more accurate conditions of a surgical used suture the 100% PGA fibre were prone to bulk degeneration and thus massive releases of MPs into the surrounding fluids. In comparison the non-absorbable sutures did not show signs of degeneration or disintegration within the 8 weeks.(108)

Again Shi et al. showed, the degradation and disintegration of plastics does not stop once plastics reach microscopic sizes, but instead continues into the area of nano particles. With polymers disintegrating down to oligo- and monomers. In their experiment they showed via a TOC analyser that mass distribution was skewed to particles of smaller sizes with NPs of a size smaller than 50nm contributing 72% of total NP mass.(108)

4.2.5 "Polyethylene wear Particles in synovial fluid after total knee arthroplasty" by Minoda et al.

After the conception that polyethylene wear might be a cause for aseptic loosening of total joint arthroplasties(115), the need to compare the amount and form of particles formed in different arthroplasty protheses became apparent. (112)

Minoda et al. sampled 17 patiens with total knee arthroplasties (all together 22 knees). Eleven of the knees were replaced with a posterior-stabilized total knee prothesis, the other eleven were of a type including a medial pivot. (112)

Under sterile conditions synovial fluid was obtained one year after the original arthroplasties were performed. Fluids were filtered through a 0,2µm nylon filter before being chemically digested, and centrifuged. After centrifugation particles were collected from another filter the solution was pushed through (0,1µm pores).
The particles on the filter were then fixated using a platinum based medium and analysed using scanning electron microscopy.
The total amount particles per knee was calculated after synovial fluid was aspirated and then flushed with 20ml of fresh water and reaspirated, calculating for the difference in concentration. (112)

Functionality between the two protheses was calculated in comparing multiple different knee scores, however the results were inconsistent, as two scores gave significant differences (*postoperative Hospital for Special Surgery knee score* and *postoperative Knee Society score*), whereas two didn't show a difference (*postoperative University of California Los Angeles score* and *post operative steps*).(112)

Volume, concentrations and total amount of particles was calculated for. Analysis showed a significantly higher number of particles in posterior stabilized knee protheses ($1.16 \pm 0.57 \times 10^8$) as compared to medial pivot prostheses ($9.01 \pm 2.95 \times 10^6$). However no significant difference in concentration of particles in synovial fluid between the two types of prostheses could be observed. No significant difference could be observed in size and shape of the analysed particles. For both types of protheses the most common size was between 0,4 and 0,6µm.(112)

4.3 Discussions and limitations

While the five analysed studies have similar fields of interest, their methods, results and limitations due differ in some relevant markers. I will therefore first summarize the authors analysis and discussion as well as each studies' limitations before comparing them between each other to draw conclusions where possible.

Shi et al.(108) conclude that, PGA has the quickest deterioration, with signs of bulk releases being quite common. Such bulk releases could potentially pose a bigger risk to macrophages and other cells coming in contact as they tend to have sharper edges and lead to stronger inflammatory responses. The potential toxicity of additives used to slow down the process of degeneration, such as PLA and epsilon-caprolactone, which have been shown to cause toxicity in laboratory studies on bacteria, was also discussed.(116)
A suture purely made of PGA releases on average 0.63 million MNPs cm^{-1} in their SBF. Yet the limitation that this SBF does not represent true stresses experienced by sutures used in actual surgical settings is proposed. In discussing this the authors refer to studies

showing up to 1 million load cycles in joints per year and stronger inflammatory effects in the body potentially aiding in degradation. (117)(108)

Yang et al.(110) focused on discussing the accumulation of MNPs in patients undergoing cardiovascular surgery. The most important conclusion is that MNPs are more abundant in blood post-surgery as compared to pre-surgery, that these particles tend to be larger than particles entering the body on "normal" routes such as the intestines or the lungs and that there are novel components found in patients' blood after interventions. All these facts lead to the conclusion that particles must be introduced during the procedure.

On top of this analysis found that the most abundant particles directly corresponded to the instruments used during surgery. As examples the previously not detected PU was given, which is used as a protective membrane to reduce the chance of autocontamination from the patients' skin into the surgically opened cavity.

Limiting to the power of the study is the small sample size of 15 patients included, as well as the filters which had pores of 1µm, but only particles from a size above 20µm were analysed. (110)

Just like Yang et al., Liu et al.(109) could show that after the intervention on patients who needed a PCI the level of MNPs rose by more than a factor of 20 in the blood. While the concentration did drop after a few hours, even after more than 12 hours they remained 10 times the original level. As they only measured blood contents in this study, the authors had no idea where the filtered-out particles might have gone but proposed like Yang et al. that they might accumulate in certain tissues.

As the second experiment MPs in the wash out of instruments classically used in surgical, interventional and day to day clinical settings were measured. MNPs were found in almost all probes, leading to the conclusion that not only large interventions such as PCI have the potential to increase MNPs circulating in the bloodstream, but also most standard procedures, such as drawing blood, invasive blood pressure measurements and similar methods.

The lower size limit of MNPs was set at 20µm as filters with pores of that size were used. Also discussed was the potential problem of chemical digestion of biological entities and the possible degradation it causes on MNPs before analysis.(109)

In their paper Field et al.(111) show clearly that MNPs concentrations in operating theatres are higher during working hours than at night. The authors draw a direct correlation between the number of hours operated and the amount of MNPs suspended in the air. Compared to other studies where other materials were found to be the predominant contamination, Field et al. found PET to be most abundant. As explanation they suggest the ubiquitous usage of PET in blister packs used to keep sterilized equipment protected from contamination. All together the PET amounted to 38% of all plastic particles with an average fallout of 451MP per day and m^2. The idea the PET-particles might stem from packaging sources is supported by their shape, as they mostly consist of shear fragments, most congruent with the mechanics of tearing open packaging.

As no organic materials were sampled, Field et al. deemed it not necessary to chemically digest the samples, which already differentiates the analysis from the other studies. A filter made from aluminium oxide composite with pore sizes of 0,2µm was used in filtration and µFTIR was used for the analysis, making another step of washing the filter and putting the MNPs into a scannable medium necessary. 70% match was set as the threshold for analysis, as compared to the 80% set in the studies using Raman-spectroscopy. As further limitations the short study period with relatively few operations was given. Lastly only a quarter of each of the used filters was analysed as it was already calculated for statistical significance, yet this leaves the potential for severe distortion.

Discussions and limitations in Minoda et al.(112) are largely kept to clinical scores for knee arthroplasties.

Their study limitations on the other hand do show similar patterns to the other papers. Filters of a pore size of 0,1µm were used in this study, still the smallest range of particles showed the largest percentage of all particles. In this study chemical digestion was used to rid the probes of biological contamination. And scanning electron microscopy was used to analyse the caught particles. No indication was given to the threshold of equivalence to be accepted as a matching PE particle.(111)

4.4 Synthesis

While all the studies have a common goal, to prove the potential dangers of MNPs accidentally introduced into the human body during surgery, their methods do differ quite a lot. Even though some of their results do show similar tendencies, overall, their methodology and area of research does differ too severely to allow for a quantitative synthesis.

If one compares the studies on the qualitative side one can quickly gauge their differences as shown in TABLE 1.
Three studies performed in humans with samples taken from three different kinds of organs, namely heart, blood and joints, the other two were not performed in humans at all. In the five studies four different kinds of MNPs were found to be the most prevalent. With only PET being the most relevant particle in Field et al.(111) and Yang et al.(110).

Even though the most abundant particles are different in almost all studies, the three studies not looking for one particular kind of particles, like Minoda et al.(112) is looking at PE or Shi et al.(108) at PGA, do find the same six to nine most used kinds of plastics. This conforms to the previously established literature, where authors put forward that almost all MNPs can be attributed to just these most important kinds, namely PET, PS, PE, PVC, PU, PA, PTFE, Nylon, PP, PMMA and PC.

While the overall amount and the size found in different environments do differ a lot, overall, the smallest looked at particles seem to be exponentially more abundant than larger ones. Independent of the sample taking procedure or the origin of the sample. All the studies show the same graphs with the highest concentrations just before the smallest analysed particles. This hints to one of the main concerns all the studies have in common. While filters and microscopes have come a very long way and todays' methodologies are able to achieve incredible resolutions, NPs still seem to fall through with a significant part being missed in the studies. Shi et al.(108) knowing how much of the PGA must have disintegrated, suggest a number up to 70% of disintegrated mass might exist in the range of 50nm and smaller.

A further limitation put forward by the studies conducted in humans, is the necessity to chemically digest the probes taken to get rid of any biological material with the possibility to interfere with the microscopic analysis. All three of them used different cocktails, concentrations and durations of digestion, with Minoda et al.(112) only using NaOH (sodium hydroxide), Liu et al.(109) using HNO_3 (nitric acid) and Yang et al.(110) using a combination of the two chemicals.

5 Discussion

5.1 Answers to the research question

Upon researching for the posed research question, it has become apparent that the field of micro and nano plastics in the environment is a relatively novel branch of scientific inquiry. While more papers have been published in recent years, research found under the search terms presented in the methods section has been limited.

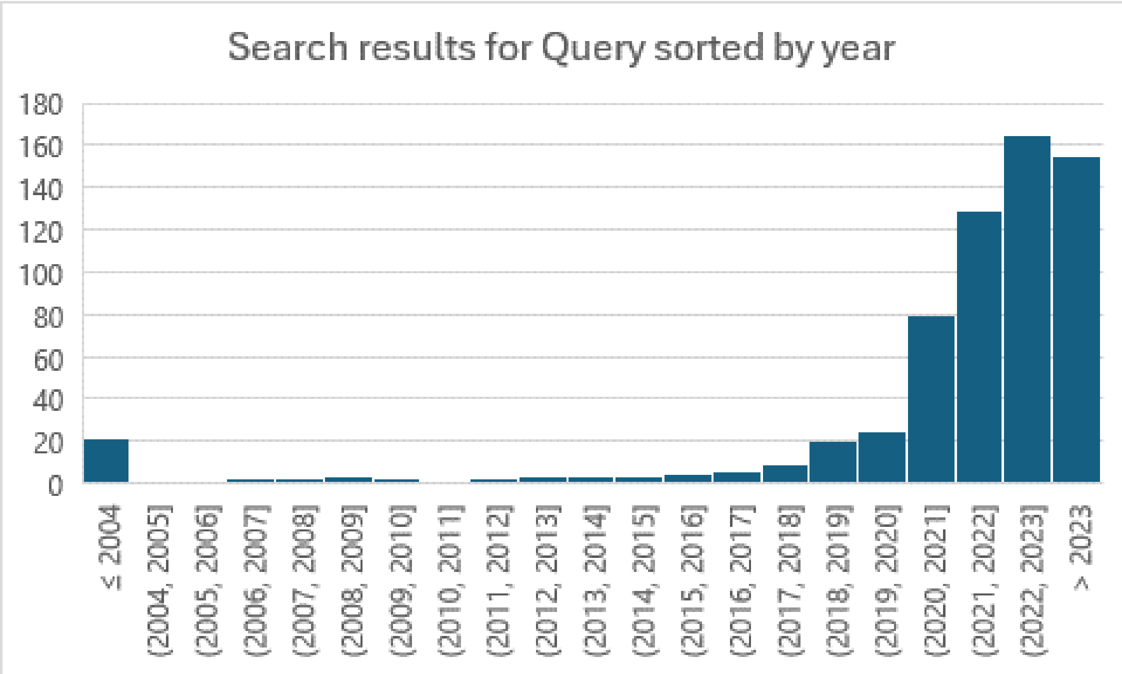

Figure 3 Bar chart showing the years of publishing of papers found in query related to research question

With the term "microplastic" being coined only in 2004 research in this field has not existed much longer than two decades. As can be observed in the chart presented above, for the most part of these two decades barely any publications concerning the subject of this specific inquiry has been published with microplastics becoming a so-called hot topic only in the past few years.

In answering to the first research question one can only point to the few studies discussed earlier in this thesis. The search of the entire scientific literature over the past twenty years only gave five viable studies, four if Minoda et al. is not to be counted as it was published outside the 20-year window used as a filter for the search query and was only included for the value of its research. Overall, this points to a severe lack of published data, yet the few studies published do paint a clear picture of contamination of surgical instruments and the surgical environment in general.

This is why the first null hypothesis of the literature indicating a contamination of surgical environments must be kept.

Once it comes to the second part of the posed research question, whether this contamination has a negative health effect on patients undergoing surgery, the answer is less obvious.

As established earlier ever more research points to the potential dangers posed by MNPs. This includes the potency to cause chronic inflammation and cancer, as well as endocrine disrupting properties. These properties have by now been firmly studied and reviewed in multiple different papers. Yet when it comes to surgery it is unclear whether the relatively short exposure in surgical environments falls into weight as compared to constant exposure via ingestion or inhalation in day-to-day life. Still the bypassing of natural barriers and direct introduction of particles into the blood stream and other protected areas of the body in surgical procedures are a cause of concern.

Therefore, no clear answer can be given on the second research question and more research is needed to conclude if MNPs pose a significant risk to patients undergoing surgery.

5.2 Conclusions

The problem of microplastics and their impact on the human body is an emerging field of research. The number of publications in this field has virtually exploded with new papers being put online daily. As shown MNPs contaminate the surgical environment and are introduced into the human body during surgery. While studies showing negative effects of MNPs in the body do exist, they are mainly performed in the aspect of environmental exposure to MNPs. The rather limited literature on microplastics in surgery presented in this thesis cannot by itself claim to prove harmful interactions in the human body. Therefore, it must be concluded that more research is needed to elucidate missing information.

5.2.1 A plea to reduce single-use plastics in the OR in terms of climate and environmental concerns

While the science on MNPs as a major source of disruption in surgery is not clear at this point in time, the results in other fields of research are.

With the world facing two major crises on the environment at the moment, namely the climate crisis and a collapse in the biodiversity in ecosystems all around the planet, efforts to mitigate as much damage as possible have ramped up over the last few years. While the goal of less than 1,5°C global warming as stated in the Prais Climate Accords of 2015 seems to be an unattainable goal today, a reduction of CO_2 emissions and waste production is aspired to by most governments.(118)

To achieve these goals major changes in the modern systems of economy and wider society will be necessary, this includes the healthcare sector. Calculations hold healthcare accountable for up to 8% of CO_2 emissions in highly developed nations such as the Netherlands, Belgium or the US, with an international average of 5,5%.(119,120)

Even though surgical interventions are only a small part of the larger system, they do over proportionally contribute to CO_2 and waste production. With some sources having found an average 146kg – 232kg of CO_2 equivalents per operation being emitted in hospitals in North America and the UK.(121) Yet not only the CO_2 production, but also the generation of surgical waste from single use plastics is a significant problem, where hospitals have been found to average 12kg of waste production per operation.(121,122)

Such numbers are staggering if brought to a global scale, and yet studies found the reduction of waste in the OR to be entirely feasible, reducing volatile anaesthesia gas (all very potent greenhouse gases) usage, by switching to total intravenous anaesthesia as well

as using reusable so called rigid sterilisation containers (as are used in most European ORs) might already have a big impact.(119,121)
This reduction of plastic waste to mitigate climate change and alleviate the destructive pollution of our ecosystems ties perfectly into the potential necessity of single-use plastic reduction in ORs to protect patients from the potential harms of MNPs. Therefore, most actions to reduce one might also attain goals in the other sector, strengthening arguments for solutions to both problems.

5.3 Critical reflection / limitations on content and method

The scope of this thesis was to establish the literature on microplastics in the surgical environment. While a preliminary analysis of the recovered publications has been accomplished, the data for a true systematic review with a thorough meta-analysis is still lacking. This severely limits any recommendations the author can give on proper behaviour in the surgical setting when it comes to microplastics.
The search terms where expanded multiple times to achieve higher sensitivity in the search query, but a less impactful paper or other publications concerning singular plastic microparticles like the one by Minoda et al. from 2003 might have been missed.

5.4 Implications on theory and praxis

As established in this thesis, not enough research has been published at this time to conclusively give recommendations on the behaviour of surgical staff, or even whether a change in behaviour is truly necessary when it comes to the protection of patients against microplastics. Yet theory suggests problems might arise, which is why it would probably be wise to reduce single use plastic items in surgical settings where possible.

In the change towards a more circular economy a trifactor of waste reduction has been proposed: “reduce”, “reuse” and “recycle”. As waste reduction for environmental reasons and human health go hand in hand, these mantras might be adopted for the problem at hand here.

In practice the goal to reduce plastics used in ORs might mean three things.
One, reduce unnecessary usage, opening and sterilization of equipment wherever possible.
Second, many surgical appliances have originally been built out of reusable and sterilisable materials such as metals and alloys. Yet they often have been switched to single-use versions, as plastics have been incredibly cheap to produce. The perfect example would be the usage of single-use plastic trocars in minimal invasive surgery.
Third, as todays plastics are rarely truly recycled but rather down-cycled, the introduction of truly recyclable materials might be necessary wherever plastics cannot be avoided. This might not directly affect the reduction MNP pollution in ORs, yet a holistic view on plastics has to be kept in mind as they do bring some advantages many other materials just cannot compete with at this moment.

5.5 Outlook and suggestions for further work

In this scoping literature review, the existing literature on microplastic in surgery was acquired and analysed. While the contamination of the surgical environment and instruments with MNPs has been established, not nearly enough research has been published to say conclusively that it poses a risk to patients and if so on what scale. Therefore, more research will be needed in the future to illuminate this hitherto underrepresented topic of science.

Potential research could investigate the possibility of filtering the air in surgical theatres, a new standard procedure to clean surgical single use instruments made of plastic to reduce their shedding of particles or similar studies.
Other fields of interest would include, whether MNPs introduced during surgery and therefore bypassing the bodys natural barriers, such as the intestinal lining, the skin or the lungs epithelium, could cause more harm than the particles encountered in daily life.

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