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DISPOSAL OF ORTHODONTIC ALIGNERS: A REVIEW

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Abstract

Orthodontic aligners have gained immense popularity as a discreet and effective method for correcting malocclusions and achieving a straighter smile. However, with their widespread use, the question of how to dispose of orthodontic aligners responsibly has emerged. This review article explores various aspects of the disposal of orthodontic aligners, encompassing environmental concerns, material composition, recycling options, and best practices. By understanding the proper disposal methods and their ecological impact, orthodontic practitioners and patients can contribute to a more sustainable orthodontic treatment process.

Keywords: Orthodontic aligners, evolution, clear aligners, environmental impact, plastic pollution, responsible recycling, disposal protocols, aligner composition, global adoption, orthodontic treatment.

INTRODUCTION

Orthodontics, which began as a branch of dentistry in the early 1900s, has evolved dramatically over the years, moving from the use of metal rings cemented to teeth to bondable metal brackets and monocrystalline ceramic brackets. This journey of transformation culminated in the development of clear aligners, representing a revolutionary leap in orthodontic technology. Towards the end of the previous century and the early years of this century, the first orthodontic aligners emerged. This ground-breaking innovation was largely driven by patient demand for orthodontic treatment that was not only effective but also more aesthetically pleasing, comfortable, and inconspicuous.[1] Consequently, aligners quickly gained popularity, with an ever-

increasing number of patients choosing this approach for orthodontic correction.[1] The use of aligners has brought about a significant shift in the field of orthodontics, making orthodontic treatment accessible and appealing to individuals of all ages, including older adults seeking solutions for malocclusion. The aesthetic appeal of aligners has not only transformed orthodontics but has also had a substantial impact on global markets. This exponential surge in aligner utilization, while beneficial for orthodontic patients, raises an important concern - the escalating generation of biomedical waste associated with aligners. It is crucial to recognize the potential environmental impact of discarded aligners, as they are predominantly composed of non-biodegradable plastics. These plastics can persist in the environment for centuries, posing a significant threat to our planet. As a result, the disposal of aligners requires careful consideration. Proper management of biomedical waste (BMW) in the context of aligners is of paramount importance. The World Health Organization (WHO) has affirmed the need for governments to allocate resources towards the establishment, support, and maintenance of efficient waste management systems.[2] These systems incorporate advanced methods and devices to reduce the volume and toxicity of clinical waste. Additionally, non-governmental organizations are keen to implement initiatives that contribute to this crucial endeavor. In light of this backdrop, our review article explores the multifaceted aspects of orthodontic aligners, delving into their composition, global adoption, and the pressing environmental concerns surrounding their disposal. Understanding the historical evolution, material characteristics, and ecological implications of orthodontic aligners is essential for both practitioners and patients as they navigate the evolving landscape of orthodontic treatment while being mindful of its ecological footprint.

COMPOSITION OF ORTHODONTIC ALIGNERS

Orthodontic aligners, a modern marvel in orthodontic treatment, offer a discrete and patient-friendly alternative to conventional braces. These orthodontic devices are primarily constructed using specific thermoplastic materials, chosen for their unique properties that significantly influence treatment efficacy and overall comfort. The key materials utilized in orthodontic aligner manufacturing are polyurethane-based materials, ethylene-vinyl acetate (EVA), and polycarbonate. Polyurethane, a versatile polymer, stands out for its remarkable clarity, rendering aligners nearly invisible when worn. This transparency is instrumental in addressing the aesthetic concerns of patients. Additionally, polyurethane's flexibility enables the aligners to exert controlled and gradual forces on the teeth, guiding them into their desired positions over time. Importantly, it's biocompatible, ensuring patients' safety and comfort throughout the treatment journey. EVA is another favored material known for its pliability and clear appearance. It allows for the creation of custom-fit aligners, ensuring that each set is uniquely molded to match the patient's dental anatomy. Moreover, EVA materials are free from harmful substances such as phthalates and bisphenol-A (BPA), further enhancing the safety and well-being of patients during orthodontic treatment. For cases that require more rigidity and strength, polycarbonate-based aligners come into play. While they may be slightly less transparent than other materials, polycarbonate aligners provide structural support, ensuring effective tooth movement, particularly in complex cases.[3]

PROPERTIES OF ALIGNER MATERIALS

The properties of orthodontic aligner materials play a vital role in their effectiveness and patient experience. First and foremost, the exceptional transparency of these materials ensures that orthodontic aligners are nearly invisible when worn. This transparency alleviates patients' self-consciousness, allowing them to undergo treatment with confidence. Customization is another significant advantage. Aligner materials can be precisely molded to fit each patient's unique dental anatomy. This tailored approach results in a snug and comfortable fit, ultimately optimizing the effectiveness of orthodontic treatment. Furthermore, the inherent flexibility of these materials is key to their success. Orthodontic aligners can gently and consistently exert pressure on the teeth, guiding them into their desired positions over time. This controlled pressure is pivotal

in achieving successful orthodontic outcomes. Biocompatibility is another essential aspect. Aligner materials are biocompatible, which means they are safe for intraoral use. Patients can wear these aligners without fear of allergic reactions or adverse responses from oral tissues. Finally, the durability of the materials used in orthodontic aligners is noteworthy. These materials can withstand the forces generated during the orthodontic treatment process, ensuring the longevity of the aligners and their continued effectiveness throughout the treatment course. In summary, understanding these material properties is crucial for both orthodontic practitioners and patients, as they significantly influence treatment success and the overall patient experience, allowing for confident and successful orthodontic outcomes.[4]

GLOBAL DENTIST PREFERENCES FOR ALIGNERS

The global clear aligners market, valued at USD 4.1 billion in 2022, is projected to experience substantial growth with a compound annual growth rate (CAGR) of 30.08% from 2023 to 2030. Clear aligners, which are custom-made orthodontic systems designed to correct misaligned or crooked teeth discreetly and conveniently, have gained significant popularity. The market's growth is attributed to factors such as an increasing patient population with malocclusions, continuous technological advancements in dental treatments, and a rising demand for customized clear aligners, driving the overall market expansion.[5] The adoption of clear aligners, such as Invisalign, increased significantly among adults and teenagers during the pandemic, as people were reluctant to visit orthodontists for traditional braces, leading to greater adoption and sales. Technological advancements in the field of orthodontics, including 3D impression systems, additive fabrication, and digital scanning technology, have made orthodontic treatments more efficient and predictable. Clear aligners are created using virtual digital models, computer-aided design (CAD-CAM), and thermoformed plastic materials like copolyester or polycarbonate plastic. These materials are chosen for their flexibility and comfort, in contrast to the discomfort and inconvenience caused by metal and ceramic braces. Invisalign is one of the leading producers of clear aligners, along with other brands such as Clear Correct, Inman Aligner, and Smart Moves. The treatment duration typically ranges from 6 to 12 months, depending on the severity of orthodontic issues. The market is dominated by materials like polyurethane, which offer advantages such as strength and durability. Polyurethane is suitable for both hard and soft components, making it an excellent choice for aligners.[5] End-use primarily involves standalone practitioners who have readily adopted clear aligner systems and are equipped with advanced digital technologies. Players such as Align Technology, Dentsply Sirona, Straumann, Envista Corporation, and others are actively contributing to the market's growth and innovation.[5]

ENVIRONMENTAL IMPACT OF ORTHODONTIC ALIGNERS

It's worth noting that a substantial environmental concern arises from the estimated 25 million dental aligners that find their way into general waste landfills annually.[6] This staggering number underscores the significant volume of discarded aligners that could potentially end up in our oceans. This influx of worn aligners in landfills exacerbates the environmental impact, raising concerns about plastic pollution and the potential for aligners to contribute to ocean pollution. Efforts to address this issue are becoming increasingly imperative in order to mitigate the environmental consequences of aligner disposal. One of the most significant environmental concerns stemming from orthodontic aligners is their contribution to plastic pollution. These aligners are commonly crafted from non-biodegradable plastics like polyurethane or copolyester. The enduring nature of these materials means they can persist in the environment for centuries, further exacerbating the global plastic waste crisis. As patients regularly replace aligners during their treatment, the cumulative effect of discarded aligners adds to the environmental burden. The same durability and resistance that make aligners effective for orthodontic use also render them resistant to decomposition, intensifying the pollution problem. The disposal of orthodontic aligners presents distinctive challenges. Owing to their small size and subtle appearance, aligners are susceptible to being misplaced or improperly discarded.[7] This often results in aligners

finding their way into landfills and even oceans, thus contributing to the growing issue of plastic waste. Improper disposal not only affects the environment directly but also raises concerns about the potential introduction of microplastics into the food chain, with associated risks for aquatic life and ecosystems. It is imperative to emphasize the importance of proper aligner disposal to address these environmental challenges effectively.[8]

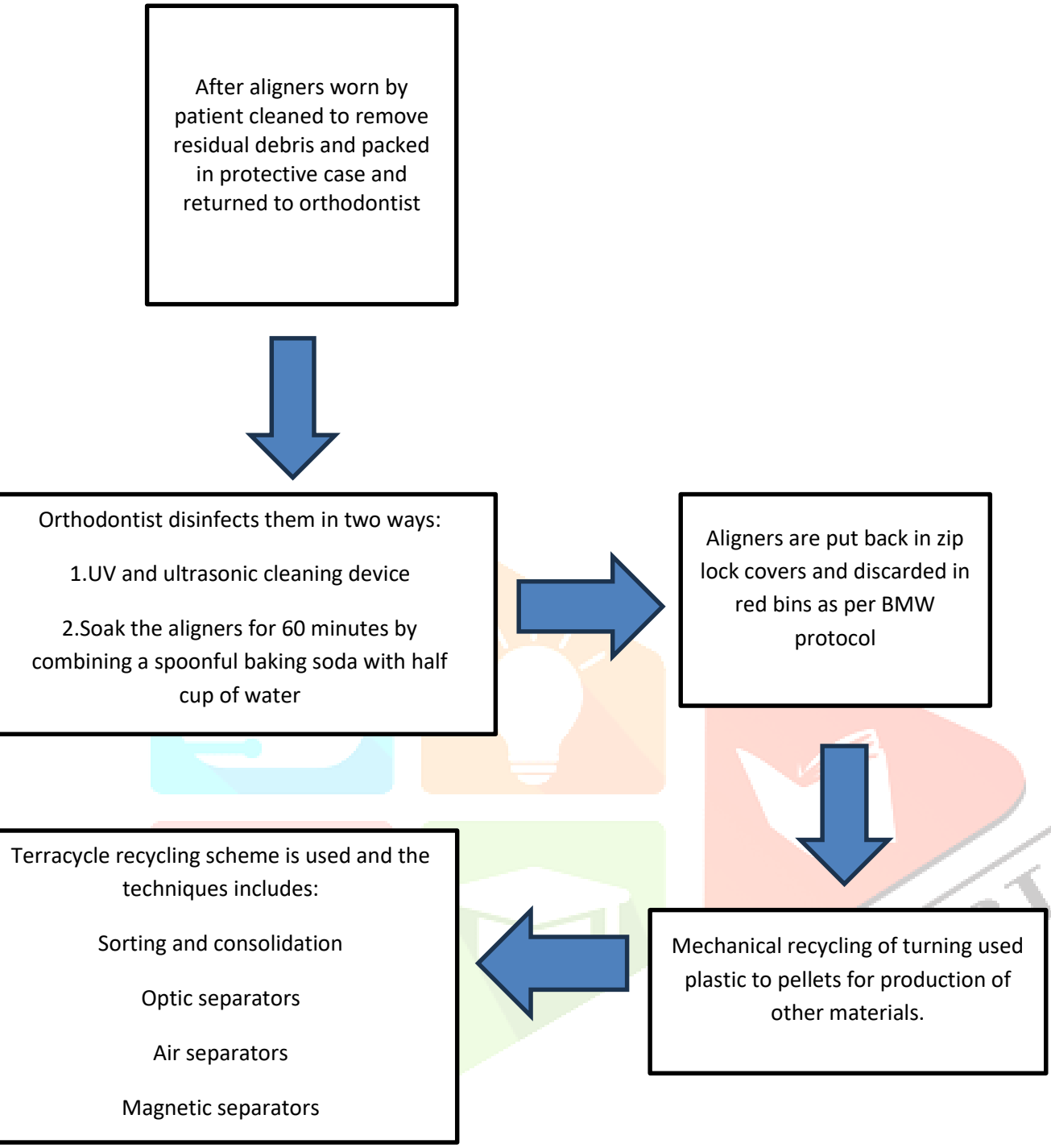
RECYCLING OF THE MATERIALS

Aligners, are crafted from medical-grade plastics. Consequently, they should not be casually tossed into regular waste bins. Invisalign makes it clear that "Invisalign aligners and Vivera retainers are classified as class IIa medical devices with CE marking in accordance with the Medical Device Directive 93/42/EEC." This classification designates your used aligners as medical waste, necessitating their responsible recycling. Aligners are constructed from a multi-layered polymer that combines different types of plastics. This blend provides the necessary rigidity and elasticity required for tooth movement during the realignment process. However, the presence of various plastic types in aligners means that they cannot be handled through conventional household recycling procedures. Spotlight Oral Care, in partnership with Terracycle, has launched a program to recycle dental aligners of any brand, their flexible plastic packaging, and even plastic aligner cases. Terracycle specializes in recycling materials that are typically considered "non-recyclable." Their network of collectors spans across 20 countries, diverting waste away from landfills and incinerators. Once collected, aligners, flexible plastic packaging, and cases undergo a thorough recycling process. They are cleaned and melted down to form hard plastic, which is then repurposed into new recycled products.

It's crucial to acknowledge the environmental impact of discarded aligners, which are made of non-biodegradable thermoplastic materials, particularly Polyethylene Terephthalate, known for its resistance to decomposition. Moreover, the combustion of such materials releases toxic gases like Polychlorinated biphenyls and dioxins, posing a threat to the environment and living organisms. Even trace amounts of these particles in the environment can result in severe health risks, including immune system changes, diabetes, infertility, obesity, and more. In light of these concerns, there is a pressing need to establish standardized protocols for the proper disposal of aligners. Taking inspiration from the work of Mithun et al[9], Gautam et al[10], and Saini[11] et al, the following Standard Operating Procedures (SOP) for aligner disposal have been devised.

PROTOCOL FOR DISCARDING USED ALIGNERS

With the increase in popularity and demand for clear aligner treatment we need to introspect the environmental risk posed by discarded aligners. These protocols aim to ensure that aligners are recycled responsibly, minimizing their environmental impact.[1] The patient receives their aligners along with a plastic holding box and instructions for wearing and caring for them. The patient wears it for the time that the orthodontist prescribes. The patient returns old aligners to the orthodontist after wearing them for the allotted amount of time, cleans them, and stores them in special zip-lock bags. An orthodontist disinfects them in two methods: 1. Ultrasonic and UV cleaning device 2. Baking soda and water: Soak your aligners for 60 minutes by combining a spoonful of baking soda with half a cup of water. Following cleaning, the aligners are once more placed in the appropriate zip lock and disposed of in the RED bag in accordance with management of biomedical waste protocol.[1]



Protocol for discarding used aligners[1]

Mechanical or secondary recycling is a sensible choice and consists of turning used plastic waste into pellets that can be reused in the production of other materials. This recycling produces products from one type of plastic or a mixture of different plastics. It is estimated that only 9% of the world's post-consumer plastic waste is mechanically recycled.[12]

Specific protocols should be implemented to collect hepatitis B (HBV) and hepatitis C (HCV) target agents. According to the guidelines of the Centers for Disease Control and Prevention (CDC), ethyl and isopropyl alcohol are effective against HBV.[13] According to the literature, HBV is very sensitive to 30% 1-propanol for 1 minute, while 40% ethanol and 2- propanol alcohol is required regardless of time. Another study[14] showed that 5 minutes of heat at 80 °C and UV treatment caused irreparable damage to RNA, so loss of viral RNA

replication inactivated HCV. Although disinfection with ethanol and 2-propanol also significantly reduces infectivity.

Recently, a number of dentists in the UK have taken part in the TerraCycle[15] recycling scheme for any brand of aligners that can be collected once as hard plastic. According to them, their process follows. Sorting and Consolidation: done manually and using different techniques to facilitate processing and then cleaning and processing. Optical sorters separate plastics by color or polymer type to remove undetectable impurities. Plastic sorting technology SORTEX is designed to organize and sort plastics using color and infrared cameras and special LEDs. High-definition cameras are connected to a user-defined computer program that activates valves inside the machine to filter unwanted dyes and polymers from plastic waste.[6] Air separators separate plastic using the principle of aerodynamics. In this process, controlled airflow is used as a sorting tool and the materials are sorted by density and particle size. Magnetic separators using superconducting magnets are also used to separate plastics, as they are diamagnetic materials, with newer methods using the magneto-Archimedes principle.[6] Small steps have been taken towards greening in some UK locations, but understanding the composition of aligners requires several. different layers of plastic make recycling machines and recycling a much more difficult and expensive process than regular "PET bottles".

Some countries, such as the United States, may consider equalizers inappropriate for "routine recycling" because they are classified as contaminated medical waste. One solution to this problem would be to educate professionals and patients about the importance of collecting aligners after clinical use. The orthodontists then collected the used aligners in a bin so they could be disinfected and returned to the company for recycling. This would prevent the spread of infection and give this material a suitable destination as contaminated and non-biodegradable waste[7].

CONCLUSION

As aligners continue to gain traction, it is imperative to consider the responsible disposal of these devices, characterized as medical waste. The complex composition of aligners, involving a mix of different plastics, makes their recycling a unique challenge that extends beyond conventional household methods. Recycling initiatives, such as those offered in partnership with Terracycle, provide a viable solution to mitigate the environmental impact of discarded aligners. The environmental risks posed by aligners, including plastic pollution and the release of toxic gases, underscore the urgency of establishing standardized protocols for proper disposal. These protocols, informed by existing studies, aim to ensure the responsible recycling of aligners. In the ever-evolving landscape of orthodontic treatment, aligners have undoubtedly played a transformative role. However, as we continue to embrace the advantages they offer, it is our collective responsibility to address the environmental consequences of their disposal. By adopting these protocols and taking proactive steps to recycle aligners responsibly, we can shape a future where orthodontic treatment aligns with both aesthetics and environmental stewardship.

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