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An Outlook on the Significance of Biodegradable Dental Polymers to address Plastic Pollution and promote Environmental Sustainability

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Plastic pollution is a major environmental issue that affects ecosystems worldwide. It is caused by the accumulation of non-biodegradable plastics, which take hundreds of years to degrade, if at all. The dental industry is one of the major contributors to plastic pollution, as it extensively uses acrylic-based polymers such as Poly (methyl methacrylate) (PMMA) to fabricate various dental appliances. Poly (methyl methacrylate) resin has a wide range of applications in the field of dentistry. Over the years it has gained popularity due to its versatility, economy, ease of use and most importantly, biocompatibility. Poly (methyl methacrylate) is the material of choice for fabrication of various dental appliances. It has been used to fabricate a wide range of dental appliances, including dentures, prostheses for craniofacial defects, orthodontic retainers, and splints. The material has been continuously evolving, and researchers have developed various methods to increase its strength and improve its properties. However, one aspect that has not been given importance to is its non-biodegradable nature. Most dental appliances, after their use, get discarded, and poly (methyl methacrylate) due to its non-biodegradability contaminates the environment for thousands of years as a plastic pollutant. Hence, we propose the development and use of biodegradable alternatives to poly (methyl methacrylate). This article throws light on this imminent issue and stresses upon the consequences of not switching to a biodegradable alternative.

Keywords: Poly (methyl methacrylate), Non-biodegradable, Dental materials, Sustainable dentistry

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Introduction

The use of polymers has found increasing applications in the field of dentistry. Acrylic-based polymers have been utilised to fabricate various dental appliances for over a century.[1,2] One such polymer is Poly(methyl methacrylate) (PMMA) which became a very popular choice due to its versatility, reliability and most importantly, biocompatibility.[3-7] PMMA has been used for a wide range of applications in dentistry such as obturators in newborns with cleft defects, as space maintainer appliances for children in the mixed dentition period, as dentures for edentulous patients, as prosthesis for various craniofacial defects (such as ocular, nasal, auditory prostheses), as functional appliances for growth modification in growing children, as splints to correct temporomandibular joint disorders, as active removable orthodontic appliances to bring about tooth movement, and as orthodontic retainers.[8-12]

PMMA became the material of choice to fabricate these appliances due to its biocompatibility and other advantages like economy, simple processing technique, stable colour, optical properties, and adequate strength.[6,7] Over the years, research has incorporated various methods to increase the strength of PMMA resins and improve its properties, and the material has been evolving ever since.[13-17] Until date, acrylic resin (PMMA) remains as the state-of-the-art material for fabrication of various dental appliances.

However, one aspect that has not been given importance with respect to these acrylic appliances is its potential negative impact on the environment. As we know, PMMA, although being the ideal material of choice used for fabricating dental appliances, it is non-biodegradable, and contributes in polluting the environment.[18,19] Therefore, this results in its categorization as a single-use plastic. Considering the present scenario, these products are harmful to the society and are unacceptable.

History of dental polymers

Dental polymer acrylics have been used in dentistry for several decades, and their history can be traced back to the mid-20th century. In 1937, Walter Wright and William Houston patented the first dental acrylic resin, which was made by polymerizing methyl methacrylate (MMA) in the presence of benzoyl peroxide.[6]

In the 1940s, dentists began using dental acrylics to make dentures, and the materials quickly gained popularity due to their ease of use and ability to create lifelike dental restorations. By the 1950s, dental acrylics had become the standard material for making dentures, and their use had expanded to other types of dental restorations, such as crowns and bridges.[6,7]

In the 1960s, new formulations of dental acrylics were developed that allowed for better color matching and greater strength, which further expanded their use in dentistry. One of the most significant advancements in dental acrylics came in the 1970s with the development of heat-cured acrylics, which provided greater durability and a more lifelike appearance.[2,3]

In the 1980s and 1990s, new types of dental acrylics were developed that allowed for greater customization and improved bonding with tooth structure. These materials included light-cured and self-curing acrylics, which could be used for a wider range of dental restorations and required less preparation of the tooth structure.[3,6]

Today, dental polymer acrylics continue to be an essential material in modern dentistry, and new formulations and techniques continue to be developed to improve their properties and expand their applications. They are used in a wide range of dental restorations, including dentures, crowns, bridges, and orthodontic appliances,

and are an essential component of modern dental practice.

Impact of non-biodegradable dental polymers on the environment

Pollution caused by plastic materials, especially the single-use plastics, is a very serious problem that is affecting the entire world. These plastic materials take a very long period of time to degrade or decompose under natural conditions, ranging from decades to millenniums and even longer at times. As a result of this long timeframe, the discarded materials cause nuisance to the environment, and most often disturbs the local ecosystem. One way to reduce the impact of plastic pollution is to recycle the plastic products after their service life. However, recycling has its own limitation. Firstly, the recycled material almost never matches the properties of the original virgin materials, leading to deterioration of the product quality or use in another product of lesser property demand.[20] Secondly, there is a limit to the number of times a material can be recycled. Therefore, after a certain number of recycling cycles, the material has to be eventually discarded or used in purposes such as laying of roads, landfills etc. Keeping the above aspects in view, the best way forward is to use biodegradable plastic, in the first place, to fabricate the original product. This will ensure that after the service life we will not have to worry about the fate of the material, as it will get biodegraded over time and mix with the soil. This is especially applicable for products using single-use plastic materials.

One such single-use plastic-based products are orthodontic baseplates (OBPs). In the field of Orthodontics, we can see that PMMA is used to fabricate the baseplate of various appliances known as Orthodontic baseplates (OBPs). As previously mentioned, appliances like the removable orthodontic appliances and orthodontic retainers, both which play an important role in orthodontic treatment use PMMA as the material of fabrication of the bulk of the appliance which is the baseplate. PMMA, comes under the category of non-biodegradable plastics; and therefore, after the service life of the base plate, it gets discarded and serves as an environmental pollutant. There have been some efforts to develop biodegradable alternatives to PMMA and other acrylic-based polymers in dentistry. These alternatives are made from natural materials such as cornstarch, cellulose, and chitosan, which are biodegradable and pose no harm to the environment.

Removable orthodontic appliances are short-term wear appliances, their usage ranging from 6 months to 24 months.[21] Universally, 35% of growing children require orthodontic treatment and more than half of these patients are provided with a removable appliance as a part of routine treatment.[22] Functional appliances, most commonly the twin-block appliance is used most commonly in growing children as means of growth modification in skeletal class II patients. Non-biodegradable plastic (PMMA) is used the fabricate these functional appliances. In summary, we provide 35% of growing children with one or two courses of functional appliance therapy with non-biodegradable plastic.[23] Also, all orthodontically treated patients, both adult and children require a course of retention using retainers to maintain the teeth in the corrected position. There are fixed and removable means of retention, of which the removable retainers are the most preferred choice of most clinicians. The routinely used Hawley's retainers are also fabricated from PMMA.[24] We estimate that around 25% of our population will have some kind of non-biodegradable appliance in their life. However, the impact of this non-biodegradable plastic is not just for the medical and dental community but also for all

of us in this planet. After these appliances have been discarded after their short course of usage, it takes 1000s of years to degrade. This a huge burden for the environment and has to be replaced with a more environment friendly appliance. We should aim at prevention of use of single-use plastics and ensuring biodegradation of the product after its service life.

A point to ponder upon is, the acrylic that is being discarded is not just the appliances that is being delivered to patients, but that which is being used for academic purpose as well. Undergraduate dental students and prosthodontic and orthodontic residents have to fabricate these appliances as a part of their curriculum. India has over 300 dental colleges with over 30,000 undergraduate students and 400 orthodontic and prosthodontic residents being admitted to the course every year.[25-27] According to the Dental Council of India regulations, every student has to fabricate at least 10 such appliances.[28,29] This shows that the amount of acrylic being used to fabricate appliances for academic purposes is enormous. There will be tonnes of acrylic being disposed every year that will not degrade and contaminate the environment.

Apart from the applications of PMMA in orthodontics, it is its applications in prosthodontic which also play a very crucial role. India has a large geriatric population of 77 million, comprising 7.7% of its total population.[30] One of the major handicaps in the elderly is loss of teeth, affecting their mastication, dietary intake and nutritional status. These patients require a dental prosthesis to rehabilitate their dental health. These dentures were the first dental appliances to be fabricated using PMMA and still exist as one of the most used appliances fabricated from PMMA. It is advised to replace these prostheses once every five years.[31] The disposal of these prostheses also obviously contribute in polluting the environment. Also, the temporary crowns are also fabricated using PMMA resin.

Other limitations of non-biodegradable poly (methyl methacrylate):

Apart from their non-biodegradability and single-use nature, there are some more drawbacks of Poly (methyl methacrylate) as a material for dental appliance fabrication and the subsequent fabrication process. The most important of which is the presence of residual monomer and initiator within the final product. During the polymerization process, some monomer and initiator do not get consumed and become trapped within the polymer network. These trapped chemicals gradually get released during the service life of the appliance, which can cause various health issues within the patients subjected to long-term exposure. Harmful chemicals (such as methyl methacrylate monomer, peroxide initiator, etc.) are leached out during its service life.[32-34]

The residual methacrylate monomer that can leach out causes mucosal irritation and altered physical properties of the product. Methyl methacrylate (MMA) monomer is a skin, eye, and respiratory tract irritant, and its prolonged exposure can cause dermatitis, asthma, and even cancer. The peroxide initiator used in the polymerization process is also a skin and eye irritant and can cause severe allergic reactions. The leaching of these chemicals from the polymer can cause mucosal irritation, allergic reactions, and altered physical properties of the product, leading to reduced efficacy and increased risk of failure.[32-34]

In addition, although the fabrication of PMMA-based OBPs is simple and quick, the products formed have structural defects, dimensional imperfections and non-uniformity, causing huge variations in their final physical and mechanical properties and may lead to breakage during use. Recently a

Poly(lactic) acid- based material has been suggested to replace the state-of-the art PMMA-based acrylics in orthodontic application.[35] However as it is a preliminary report further research is required to deem such materials as a practical replacement material and to extend its application in all dental specialities.

Due to the above-mentioned reasons, it becomes an important topic of interest for researchers to look for alternative materials that can replace PMMA-based acrylics in dental applications. Poly(lactic) acid or (PLA)-based material, which is biodegradable and safer than PMMA has the potential to replace it for dental applications due to its favourable mechanical properties, biocompatibility, and biodegradability. However, further research is required to evaluate its long-term performance and to extend its utility in all dental applications.

With the increasing awareness of the impact of plastic pollution on the environment, it is essential to explore and promote the use of more environmentally friendly biodegradable alternatives in dentistry. This would not only help reduce plastic pollution but also ensure that the dental industry is sustainable and eco-friendly.

Conclusion

To conclude, we would like to say that there is an imminent need to find an alternative biodegradable material to replace non-biodegradable PMMA as a single-use plastic in the field of dentistry.

Nevertheless, considering the present thrust of the society and governments all over the world, it is a sort of compulsion to move towards biodegradable products irrespective of their higher cost. A new biodegradable and environmental-friendly product will be a welcome innovation for all the medical and dental professionals across the globe and will be of benefit to the entire population. Future research should be carried out to develop a material that is biodegradable, biocompatible and mimicking all the properties of PMMA.

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