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Knowledge among dental professionals on proper aligner disposal: A questionnaire-based study

Bharti Chandra*, Yogesh Mahobia, Vini Akanksha Jai, Manjil Mousam Sabanya, Vibhuti Goswami & Joydeep Giri

Department of Orthodontics and Dentofacial Orthopedics, New Horizon Dental College and Research Institute, Bilaspur, Chhattisgarh, India; *Corresponding author

Affiliation URL:
https://www.nhdcri.in/

Author contact:
Bharti Chandra - E-mail: bharti.chandra40@gmail.com; Phone: +91 9826540884
Yogesh Mahobia - E-mail: dr.yogeshmahobia@gmail.com; Phone: +91 8349610690

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Vini Akanksha Jai - E-mail: drvini0207@gmail.com; Phone: +91 9977477884
Manjil Mousam Sabanya - E-mail: manjilms1@gmail.com; Phone: +91 7022156504
Vibhuti Goswami - E-mail: vibhutigoswami97@gmail.com; Phone: +91 8962696906
Joydeep Giri - E-mail: vampjoy.09@gmail.com; Phone: +91 8085032503

Abstract:
Clear aligner therapy is increasingly popular in orthodontics, but the disposal of used aligners raises concerns regarding environmental sustainability. Therefore, it is of interest to assess the knowledge and awareness of 100 dental professionals regarding aligner materials, environmental impacts, disposal practices and patient education. Awareness of aligner materials and recyclability was reported by 66% of participants, 64% recognized the environmental consequences of improper disposal and 74% identified biomedical waste disposal as the preferred method. Despite 96% supporting educational initiatives and 93% expressing interest in further training, only 28% routinely provided written disposal instructions, while 79% had not attended relevant workshops. Thus, data shows the gap between environmental awareness and clinical practice, emphasizing the need for standardized disposal guidelines, continuing professional education and manufacturer-supported recycling initiatives.

Keywords: Clear aligners, aligner disposal, environmental sustainability, microplastics, dental professionals

Background:
Clear aligner therapy has become a recognized treatment technique in contemporary orthodontics due to its superior esthetics, patient comfort, removability and enhanced oral cleanliness compared to traditional fixed equipment. The introduction of digital technologies like three-dimensional imaging and computer-aided design/computer-aided manufacturing (CAD/CAM) has further enhanced the accuracy and predictability of aligner therapy, resulting in its widespread acceptance by orthodontists and general dental practitioners globally **[1-3]**. The growing use of clear aligners has also sparked concerns over their environmental impact. Most of the aligners are made of thermoplastic polymers, such as polyethylene terephthalate glycol-modified (PETG) and thermoplastic polyurethanes (TPU), which have great mechanical and optical qualities but poor biodegradability. In orthodontics, several aligners must be replaced throughout therapy every one to two weeks, leading to a large amount of plastic trash during treatment. Improper disposal of these materials increases to the burden of persistent plastic waste and is a rising environmental challenge for sustainable dentistry practice **[3-5]**. Recent studies have indicated that transparent aligners produce microplastic particles throughout their clinical use and may have significant environmental and health consequences. Moreover, the disposal practices like incineration or indiscriminate disposal can also be adding to the environmental contamination. Therefore, there is an increased interest in the development of biodegradable materials, recycling strategies and environmentally sustainable ways in aligner therapy **[6-8]**. Sustainable dentistry is the ethical use and disposal of dental materials to reduce the environmental impact of dental practices without compromising standards of patient care. Dental professionals play a vital part in this by teaching patients on how to dispose of these products properly and by taking steps to handle this trash in an environmentally sound way. However, there are no standardized recommendations for the disposal of used aligners and clinicians' awareness about their recyclability, environmental impact and proper disposal practices seems to be variable. These inadequacies can have negative impacts on patient practices and lead to unwarranted environmental contamination **[5, 8 and 9].** Therefore, it is of interest to evaluate the knowledge of dental professionals about the proper disposal of clear aligners.

Materials and Methods:
The present cross-sectional questionnaire based study was done to examine the knowledge of dental professionals on the proper disposal of clear aligners. Ethical approval was received from the Institutional Ethics Committee prior to the start of the investigation. All participants provided electronic informed consent prior to data collection. The sample size was calculated using OpenEpi software at 95% confidence level with 50% predicted frequency and 5% margin of error. A minimum sample size of 109 people was needed. General dentists, orthodontists, postgraduate students and academicians interested to participate were invited to fill out the survey. A total of 109 participants were approached and 100 responded to the questionnaire, giving a response rate of 92%. Exhaustive literature research was carried out and a standardized self-administered questionnaire was devised. The questionnaire was composed of two parts. The first segment was about demographic and professional features as gender, kind of practice, practice location and duration of aligner's usage. The second part was dedicated to the knowledge about the composition of the aligner materials, recyclability, environmental impact, disposal process, patient education procedures and the necessity for professional training on aligner disposal. The content validity of the questionnaire was examined by a panel of specialists in orthodontics and public health dentistry. Reliability was tested using test-re-test method on a pilot sample. The questionnaire showed a moderate agreement with a Cohen's kappa coefficient of 0.65. Google Forms was used to develop the questionnaire, which was delivered electronically via WhatsApp, Facebook, Instagram and email. The survey was open for three months. Participation was voluntary; confidentiality and anonymity of responses was maintained. No personal information was gathered. The data were converted into Microsoft Excel and analyzed using SPSS version 22.0 (IBM Corp., Armonk, NY, USA). Categorical variables were

summarized using frequencies and percentages, descriptive statistics. Associations between categorical variables were studied by means of the chi-square test. Statistical significance was defined as a p-value of <0.05.

Results:

The survey was completed by 100 dental professionals (response rate 92%). **Table 1** shows the demographic and professional characteristics of the participants. The majority of the participants were males (62%), from the Central area (47%) and in private practice (53%). The majority (89%) had used clear aligners in clinical practice for fewer than five years. **Table 2** summarizes the replies on knowledge of aligner disposal and awareness on aligner disposal. 66% of the participants were aware of the materials used in clear aligners and their recyclability, while 64% of the participants were aware of the environmental implications of inappropriate disposal. Almost three-fourths (74%) correctly recognized biomedical waste disposal as the right route for disposal of worn aligners. Most of the responders were aware of the importance of sustainability initiatives in orthodontic practice. Ninety-six percent of participants supported educational initiatives regarding aligner disposal and 95% felt that further research was necessary about the environmental impact of aligners. Furthermore, 96% either strongly supported or supported the development of biodegradable aligners. Almost two-thirds (67%) said the rise in the usage of transparent aligners had an impact on environmental sustainability and that dentists or orthodontists are chiefly responsible for teaching patients on proper disposal practices. However, despite this understanding, the execution of patient education was poor. Only 28% of respondents regularly provided written disposal instructions to patients, while 40% said they never did. In addition, 79% had not participated in any workshop or continuing education program on the subject of aligner disposal. However, 93% expressed an interest in receiving extra training on ecologically acceptable disposal techniques.

Table 1: Demographic and professional characteristics of the study participants (N = 100)

Variable	Category	n (%)
Gender	Male	62 (62.0)
	Female	38 (38.0)
Area of practice	North	27 (27.0)
	South	9 (9.0)
	East	14 (14.0)
	West	3 (3.0)
	Central	47 (47.0)
Type of practice	Faculty	3 (3.0)
	Private practice	53 (53.0)
	Academic and private practice	44 (44.0)
Duration of aligner use	<5 years	89 (89.0)
	5–10 years	9 (9.0)
	10–15 years	2 (2.0)

Table 2: Knowledge and awareness regarding proper disposal of clear aligners among dental professionals (N = 100)

Variable	Response	n (%)
Awareness of aligner material and recyclability	Yes	66 (66.0)
	No	34 (34.0)
Estimated degradation time of aligner material	10 years	38 (38.0)
	100 years	47 (47.0)
	500 years	5 (5.0)
	1000 years	10 (10.0)
Awareness of environmental impact of improper disposal	Yes	64 (64.0)
	No	36 (36.0)
Preferred disposal method	Recycling	26 (26.0)
	Biomedical waste disposal	74 (74.0)
Educational programs are necessary	Agree	96 (96.0)
	Neutral	2 (2.0)
	Disagree	2 (2.0)
More research is required	Agree	95 (95.0)
	Neutral	5 (5.0)
Support for biodegradable aligners	Strongly support	76 (76.0)
	Support	20 (20.0)
	Neutral	4 (4.0)
Increasing aligner use affects environmental sustainability	Yes	67 (67.0)
	No	12 (12.0)
	Not sure	21 (21.0)
Primary responsibility for patient education	Dentist/Orthodontist	67 (67.0)
	Dental hygienist	24 (24.0)
	Manufacturer	9 (9.0)
Written disposal instructions provided	Yes	28 (28.0)
	Often	14 (14.0)
	Sometimes	18 (18.0)
	Never	40 (40.0)
Attended training/workshop on aligner disposal	Yes	21 (21.0)
	No	79 (79.0)
Interested in further training	Yes	93 (93.0)
	No	7 (7.0)

Discussion:

The present study evaluated the knowledge of dental professionals on the proper disposal of clear aligners and found moderate knowledge of aligner materials and their

environmental consequences. But there were shortcomings in patient education, in the training of professionals and in the realization of proper disposal processes. Although there is an increasing interest in sustainability in orthodontics, its application in ordinary clinical practice is still limited. The growing use of clear aligners has had a significant impact on orthodontic treatment, improving esthetics and patient comfort. However, the popularity of thermoplastic aligners has also led to the development of a significant amount of plastic trash, which highlights the need for environmentally sustainable orthodontic practice **[10].** Duane *et al.* **[11]**. In dentistry stressed the importance of a complete strategy pertaining to sustainability, including waste reduction, wise resource use and environmentally sound clinical procedures to reduce the ecological footprint of oral health care. Likewise, Duane *et al.* and Duane *et al.* also stressed the necessity of efficient waste management and biodiversity protection through environmentally friendly procedures in dentistry clinics **[12, 13].** In this study, most participants were aware of the environmental repercussions of poor aligner disposal and strongly supported educational initiatives and future research linked to sustainable orthodontics. These findings are in line with the increasing focus on environmental responsibility in orthodontics. Macrì *et al.* **[5]** proposed that clear aligner therapy must be assessed not only for clinical efficacy, but also for its effects on the environment during the product life cycle, such as production, utilization, disposal and recycling. In their review they emphasise the need for environmentally responsible disposal strategies and improved awareness among professionals. The present study results showed that the awareness was widespread, but only a small number of the individuals gave written disposal instructions to patients routinely. Inappropriate disposal procedures and increasing environmental contamination may be associated with inadequate patient education as patients are responsible for the final disposal of discarded aligners. Disposal methods such as cremation of aligner materials may release numerous chemical compounds and it is suggested that indiscriminate disposal of thermoplastic aligners may adversely affect the environment **[8]**. Camcı and Büyükbayraktar also reported the possible long-term environmental risk of discarded aligners and the need to find feasible disposal procedures and biodegradable alternatives to decrease plastic pollution **[14]**. Khamatkar *et al.* and Nemisri *et al.* highlighted gaps in aligner disposal awareness and practices among dental professionals and patients, emphasizing the need for standardized disposal guidelines **[15, 16]**. Another notable finding of the present study was the low participation of dental professionals in formal training sessions about the disposal of aligners. Ongoing professional education is critical for translating scientific information into clinical practice. Bhardwaj *et al.* highlighted that sustainable orthodontics can be realized through the collaboration of doctors, manufacturers and recycling organizations to reduce the waste generation and enhance the recycling processes related with clear aligner therapy **[17]**. Similarly Cenzato *et al.* claimed that the future advances of aligner materials should be based not only on mechanical and esthetic features but also on environmental sustainability through the creation of recyclable and biodegradable biomaterials **[3]**. The absence of clear criteria for aligner disposal remains a major obstacle. Boonchanachai *et al* **[9]**. Underlined the necessity for sustainable orthodontic supply chains, including environmentally friendly production, waste management and recycling systems throughout the life cycle of clear aligner therapy. Additionally, Panayi *et al.* highlighted the growing concerns surrounding the emission of microplastics from orthodontic aligners, stressing the necessity to educate clinicians and implement evidence-based disposal practices to mitigate environmental contamination **[6]**. Al Jearah (2025) showed the importance of improving dentists' knowledge of clear aligner treatment. Collectively, these studies support structured professional education and patient awareness to promote environmentally responsible aligner disposal **[18].** The present study has a number of clinical implications. Dental professionals should regularly educate the patients on the proper disposal procedures and incorporate environmental sustainability in ordinary orthodontic practice. Dental continuing education programs should include sustainable waste-management principles and manufacturers should provide standardized disposal instructions, environmentally friendly packaging and recycling or take-back programs to reduce the environmental burden associated with clear aligner therapy. Some limitations should be considered in the interpretation of the findings. The cross-sectional design was based on self-reported responses and may not reflect actual disposal procedures. The very small sample size and online form of data collection may additionally limit the generalizability of the results. However, the present study offers useful baseline evidence of the awareness of dental professionals and supports the necessity for planned educational initiatives and standardized disposal protocols.

Conclusion:

Dental professionals showed moderate knowledge regarding clear aligner disposal, with notable deficiencies in patient education and professional training. Integrating sustainable waste-management practices into dental education and establishing standardized disposal protocols are essential to promote responsible aligner disposal. Collaboration among dental professionals, manufacturers and recycling organizations may help reduce plastic waste and advance environmentally sustainable orthodontic practice.

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