RESEARCH ARTICLE

ASSESSMENT OF KNOWLEDGE AND PRACTICE OF CLEAR ALIGNER DISPOSAL AND RECYCLING AMONG ORTHODONTISTS: A CROSS-SECTIONAL QUESTIONNAIRE STUDY

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Short title: Clear Aligner Disposal and Recycling

Source of support: Nil. **Conflict of interest:** None.

ABSTRACT

Background: Clear aligner therapy (CAT) has revolutionized orthodontic care because of its aesthetic appeal and convenience. However, the growing use of thermoplastic aligners has raised environmental concerns owing to their non-biodegradable nature and the lack of standardized disposal methods. This study aimed to evaluate orthodontists' knowledge, awareness and practices regarding the disposal and recycling of clear aligners in India.

Methods: A cross-sectional online questionnaire comprising 21 validated items was distributed to practicing orthodontists. A total of 166 responses were analyzed using descriptive statistics and the Chi-square test, and one-way ANOVA was used to assess variations in knowledge and practice scores across years of experience, area and type of practice.

Results: Only 9% of orthodontists were fully aware of the biodegradation characteristics of aligner materials, whereas 87.3% were slightly aware. Nearly half (50.6%) reported no formal in-clinic provisions for aligner disposal. The mean knowledge and practice scores were 8.60 ± 1.10 and 7.63 ± 1.17, respectively, and both were significantly influenced by years of experience ($p=0.017$ and $p<0.001$). The major challenges identified were the lack of clear guidelines (18%) and the time or effort required for disposal (29%). Encouragingly, 89% expressed willingness to adopt proper disposal methods if adequate facilities and regulations were available.

Conclusion: The study highlights a significant gap between awareness and practice of clear aligner waste management among orthodontists. National guidelines, continuing education programs and collaboration with waste management agencies are essential to promote environmentally sustainable orthodontic practice.

Keywords: Clear aligners, Waste management, Recycling, Orthodontists, Environmental awareness, Sustainability.

How to cite this article: Selvam L, Ramathirtham P, Sameemullah KH, Elias R, Rahamathulla RA, Jaypaulraj H, Palindla LP., Assessment of Knowledge and Practice of Clear Aligner Disposal and Recycling Among Orthodontists: A Cross-Sectional Questionnaire Study. Int J Drug Deliv Technol. 2026;16(89s): 730-735; DOI: 10.25258/ijddt.16.89s.78

INTRODUCTION

Malocclusion is among the most prevalent dental problems, alongside dental caries, periodontal disease and dental fluorosis,[1] and it affects physical, social and psychological well-being.[2] Orthodontic treatment improves oral function, appearance and quality of life.[3]

Once centered mainly on adolescents,[4] orthodontic care is now increasingly sought by adults to improve oral health, appearance and quality of life.[5] The specialty has progressed from cemented metal bands to bondable metal and ceramic brackets and, now, clear plastic aligners, changing how orthodontic care is delivered and perceived.[6]

Clear aligners are favored by adults for their discreet appearance.[7] Because they are removable, they permit better oral hygiene, reduce soft tissue irritation and lower the risk of the white spot lesions often seen with fixed appliances.[8,9] Virtual monitoring also allows fewer in-office visits, which suits patients who find frequent appointments difficult.[9]

The roots of modern aligners lie in Kesling's tooth positioning appliance of 1945[10] and Nahoum's vacuum-formed clear appliance of 1959.[11] In 1997, Align Technology combined 3D computer imaging with vacuum thermoforming to produce customized clear aligners.[12]

The first widely available aligners used a rigid polyurethane, later replaced by more flexible materials such as Exceed-30 and, in 2012, SmartTrack, a thermoplastic polyurethane designed to deliver gentler, more consistent forces.[13] Other manufacturers mainly use polyethylene terephthalate glycol-modified (PET-G), polycarbonate, polypropylene, thermoplastic polyurethanes and ethylene vinyl acetate,[14] with PET-G favored for its superior optical and mechanical qualities.[15] These petroleum-derived plastics are non-biodegradable and cause environmental damage when burned.[16]

The number of trays per patient depends on case complexity, the frequency of tray changes[17] and the need for refinements.[18] More than 25 million aligner trays are estimated to be discarded into landfills worldwide each year.[19]

Polyethylene terephthalate (PET) is among the most durable plastics and strongly resists natural degradation,[20] taking nearly a thousand years to break down,[21] while incineration emits dioxins and polychlorinated biphenyls that contaminate the air and endanger living organisms.[22] Global plastic use has risen nearly 180-fold since 1950, reaching an estimated 400.3 million tons by 2022, and neglect of how plastic is discarded has made it a leading source of waste in the natural environment.[23]

Information on how clear aligners are actually disposed of, and whether proper methods are followed, is limited. Surveying orthodontists can reveal knowledge and practice gaps and support responsible disposal habits among professionals and patients. This study therefore aimed to evaluate the knowledge, awareness and practices of orthodontists regarding clear aligner disposal and recycling, highlighting the importance of sustainable disposal practices within the dental profession.

MATERIALS AND METHODS

A cross-sectional online survey was conducted using a 21-item questionnaire, created in Google Forms, to assess knowledge, awareness and practices related to clear aligner disposal. Apart from the respondent's email address, no personally identifying information was collected, and the name field was optional. Institutional Review Board clearance (SVDC/IRB/2025/1102/PG SHORT STUDY/06) and Institutional Ethical clearance (SVDC/IEC-Cer/2024-25/83) were obtained before the study began.

Questionnaire Validity

The questionnaire was validated by external experts in the field for reliability and relevance. Based on their feedback, the length of the questionnaire and the clarity of individual questions were refined.

Study Population

Orthodontists practicing clear aligner therapy were included. General dentists and practitioners of other specialties were excluded.

Survey Distribution

The survey link was shared through social media platforms, particularly WhatsApp. Informed consent was outlined within the form and obtained from each respondent before the questionnaire began.

Sample Size Calculation

The sample size was calculated using the formula $N = Z^2pq/d^2$, where $Z = 1.96$ at 95% confidence, $p = 10.9\%$, $q = 1 - p$ and $d = 5\%$ (allowable error). Thus, $N = (1.96)^2 \times 0.109 \times 0.891/(0.05)^2 = 149.2$. After allowing for a 10% non-response rate (149.2/0.9 = 165.8), the final sample size was set at 166 participants.

Statistical Analysis

Data were entered in Microsoft Excel and analyzed using IBM SPSS version 25. Descriptive statistics (frequencies, percentages, means and standard deviations) were calculated. Associations between categorical variables (e.g., years of experience, type and area of practice, disposal methods and awareness) were tested using the Chi-square test, and mean knowledge and practice scores across groups were compared using one-way ANOVA. A p-value <0.05 was considered statistically significant.

RESULTS

Participant Characteristics

Among the 166 respondents, most orthodontists had 10–20 years (38.0%) or 6–10 years (36.1%) of clinical experience. Urban practitioners formed the largest group (40.4%), and most respondents worked in private clinics (66.3%) (Figure 1).

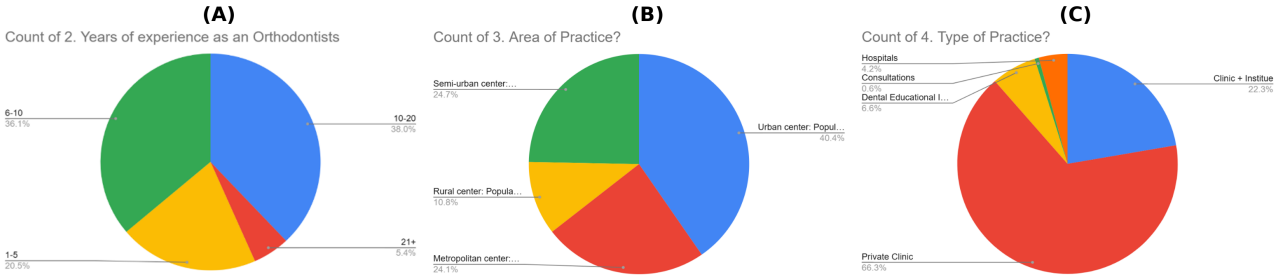


Figure 1: Distribution of participants according to (A) years of orthodontic experience, (B) area of practice and (C) type of practice

Aligner Practice Variables

Years of experience was significantly associated with the number of aligner cases treated ($p<0.001$), trays used per case ($p<0.001$), type of aligner system used ($p=0.027$) and in-house disposal methods ($p=0.029$) (Table 1). Orthodontists with 10–20 years of experience most commonly reported >30 cases (66.7%) and 30–40 trays per case (51.9%), whereas those with 1–5 years of experience most commonly reported 0–10 cases (66.7%) and 10–20 trays (80.0%). Awareness of disposal programs ($p=0.291$) and disposal options provided by companies ($p=0.466$) did not differ significantly; in all experience groups, most respondents reported that companies offered no disposal programs or provisions.

Table 1: Association of aligner practice variables with years of experience, area of practice and type of practice among orthodontists

Aligner practice variable	Years of experience	Area of practice	Type of practice
Number of aligner cases treated	**<0.001**	**<0.001**	**<0.001**
Number of trays used per case	**<0.001**	**<0.001**	**0.046**
Type of aligner system used	**0.027**	0.553	**<0.001**
Awareness of disposal programs	0.291	0.401	0.327
Disposal options provided by companies	0.466	0.219	0.189
In-house disposal methods	**0.029**	0.610	**<0.001**

Chi-square test; values are p-values. Bold values indicate statistical significance (p<0.05).

Area of practice was significantly associated with the number of cases treated ($p<0.001$) and trays used ($p<0.001$). Metropolitan and urban practitioners reported higher case volumes and tray usage than rural practitioners (for example, >30 cases in 66.7% of metropolitan practitioners versus 0–10 cases in 27.3% of rural practitioners). Aligner system preference, disposal program availability, company disposal options and in-house disposal methods did not differ significantly by area (all $p>0.05$); return kits were reported only in urban practices.

Type of practice was significantly associated with the number of cases treated ($p<0.001$), trays used ($p=0.046$), aligner system used ($p<0.001$) and in-house disposal methods ($p<0.001$). Private clinic practitioners accounted for 66.7% of those treating >30 cases and most often used multiple aligner systems (74.8%) and multiple disposal methods (72.6%), whereas biomedical waste agencies were used more often in clinic + institute settings (85.7%).

Knowledge and Practice Scores

Mean disposal and recycling knowledge and practice scores are shown in Table 2. Knowledge scores differed significantly by years of practice ($p=0.017$), with the highest mean among orthodontists with 6–10 years of experience (8.80 ± 0.91). Practice scores also differed significantly by years of practice ($p<0.001$), again highest in the 6–10-year group (7.92 ± 0.91). No significant differences in knowledge or practice scores were found by area or type of practice ($p>0.05$).

Table 2: Comparison of disposal and recycling knowledge and practice scores among orthodontists

Comparison variable	Category	Knowledge score (mean ± SD)	p-value	Practice score (mean ± SD)	p-value
Years of practice	1–5 years	8.38 ± 1.13	**0.017**	7.00 ± 1.52	**<0.001**
	6–10 years	8.80 ± 0.91		7.92 ± 0.91	
	10–20 years	8.67 ± 1.14		7.65 ± 1.11	
	>20 years	7.67 ± 1.41		7.89 ± 0.93	
Area of practice	Metropolitan	8.50 ± 1.52	0.720	7.68 ± 1.19	0.270
	Rural	8.67 ± 0.97		7.11 ± 1.49	
	Semi-urban	8.76 ± 0.73		7.68 ± 1.04	
	Urban	8.55 ± 1.03		7.70 ± 1.14	
Type of practice	Clinic + institute	8.59 ± 1.28	0.130	7.57 ± 1.44	0.650
	Dental educational institute	8.36 ± 1.12		7.18 ± 1.17	
	Hospitals	9.00 ± 1.15		7.86 ± 1.46	
	Private clinic	8.63 ± 1.01		7.68 ± 1.06	

One-way ANOVA. Bold values indicate statistical significance (p<0.05).

Disposal Awareness and Practices

Years of experience was significantly associated with the availability of disposal provisions (p<0.001), patient instructions regarding used aligners (p=0.028) and perceived disposal challenges (p<0.001), but not with methods of disposal (p=0.101). Area and type of practice were significantly associated only with perceived disposal challenges (both p<0.001) (Table 3).

Table 3: Association of respondent characteristics with disposal awareness and practices among orthodontists

Characteristic	Methods of disposal	Disposal provisions at practice	Patient instructions for used aligners	Perceived disposal challenges
Years of experience	0.101	**<0.001**	**0.028**	**<0.001**
Area of practice	0.241	0.274	0.268	**<0.001**
Type of practice	0.079	0.352	0.162	**<0.001**

Chi-square test; values are p-values. Bold values indicate statistical significance (p<0.05).

DISCUSSION

This study highlights important gaps in orthodontists' knowledge and practice regarding the disposal and recycling of clear aligners. Although most respondents knew that aligners are made of non-biodegradable plastic, only a small proportion (9%) were fully aware of their biodegradation characteristics. Nearly half (50.6%) reported no formal disposal provisions in their practice, and patient instructions on disposal were inconsistent. Knowledge and practice scores were significantly associated with years of orthodontic experience and were highest among orthodontists with 6–10 years of experience.

Aligner thermoplastics such as PET-G, polyurethane, polycarbonate and polypropylene may take hundreds of years to degrade in landfills,[14-16] and their incineration can release toxic dioxins and polychlorinated biphenyls.[22,24] Bisphenol-A release and cytotoxicity from thermoplastic aligner materials have also been reported, underlining the need for safe disposal and recycling protocols.[25-30]

Recent reviews have highlighted the environmental burden of discarded aligners and dental plastic waste and have called for proper disposal and recycling strategies,[31-33] and a systematic review of oral healthcare clinics likewise reported substantial polymer waste and critical knowledge gaps.[34] Data on orthodontists' own knowledge and practices are, however, limited, which this study helps to address.

The absence of formal disposal provisions in nearly half of the practices is concerning, because used aligners discarded in general garbage may increase environmental contamination and pose a potential risk of cross-infection.[16] Patient instructions were likewise inconsistent: although many orthodontists advised patients to clean and store used aligners, there was no uniform protocol on whether aligners should be returned to the clinic, discarded in household garbage or handed over to biomedical waste agencies. This indicates a need for unified patient education guidelines and chairside instructions.

The main barriers reported were the lack of clear disposal guidelines and the time and effort required for waste segregation and disposal. Encouragingly, most respondents (89%) were willing to adopt appropriate disposal methods if adequate infrastructure and regulations were available, suggesting that responsible practices are achievable if disposal systems are made simpler and more accessible.

Gupta et al.[24] proposed a standard operating procedure in which patients disinfect used aligners, store them in zip-lock pouches and return them to the orthodontist, who re-disinfects them and disposes of them through biomedical waste protocols; such a framework could be adapted into national guidelines. Recycling initiatives, such as TerraCycle-based programs in the United Kingdom and the United States that collect used aligners for repurposing,[35,36] show that sustainable disposal pathways are feasible when adequate infrastructure exists, although recycling remains technically difficult because of the multi-layered plastic composition of aligners.

These findings are also relevant to the United Nations Sustainable Development Goals (SDGs). Clear aligner therapy supports SDG 3 (Good Health and Well-Being), whereas the disposal of non-biodegradable aligners raises concerns related to SDG 12 (Responsible Consumption and Production) and SDG 13 (Climate Action).[37]

This study has limitations: responses were self-reported, the questionnaire was distributed through social media, and the sample of 166 orthodontists may not represent all practitioners, so the findings should be generalized with caution.

CONCLUSION

This study revealed notable gaps in orthodontists' knowledge and practice regarding the disposal and recycling of clear aligners. Although most respondents knew that aligners are made of non-biodegradable plastic, only 9% were fully aware of their biodegradation characteristics, nearly half (50.6%) had no formal in-clinic disposal provisions, and patient education on waste handling was inconsistent. Nevertheless, 89% were willing to adopt environmentally responsible practices if clear guidelines and infrastructure were available. Standardized biomedical waste management protocols, national disposal guidelines, regulatory involvement and educational initiatives are therefore needed to promote sustainable orthodontic practice and reduce the environmental burden of clear aligner therapy.

ACKNOWLEDGEMENT

The authors thank all the orthodontists who participated in this survey, and the Department of Orthodontics and Dentofacial Orthopedics, Sri Venkateshwaraa Dental College, Puducherry, for guidance and institutional support during the study.

REFERENCES

1. **Shaj F, Jayarajan J, Vijayan A, Shukoor K.** Assessment of malocclusion among patients seeking orthodontic treatment at dental college in Kerala, India. International Journal of Preventive and Clinical Dental Research. 2014;1:10-14.
2. **Yi S, Zhang C, Ni C, Qian Y, Zhang J.** Psychosocial impact of dental aesthetics and desire for orthodontic treatment among Chinese undergraduate students. Patient Preference and Adherence. 2016;10:1037-1042. DOI: 10.2147/PPA.S105260
3. **Palomares NB, Celeste RK, de Oliveira BH, Miguel JAM.** How does orthodontic treatment affect young adults' oral health-related quality of life? American Journal of Orthodontics and Dentofacial Orthopedics. 2012;141(6):751-758. DOI: 10.1016/j.ajodo.2012.01.015
4. **Singh RN, Shahi AK, Ramesh V, Sharma S, Kumar S, Chandra S.** Prevalence of malocclusion and orthodontic treatment needs among 12-15 years old school children in Patna, Eastern India. Journal of Family Medicine and Primary Care. 2019;8(9):2983-2989. DOI: 10.4103/jfmpc.jfmpc_681_19
5. **Saccomanno S, Saran S, Laganà D, Mastrapasqua R, Grippaudo C.** Motivation, perception, and behavior of the adult orthodontic patient: a survey analysis. BioMed Research International. 2022;2022:2754051. DOI: 10.1155/2022/2754051
6. **Kaur S, Singh R, Soni S, Garg V, Kaur M.** Esthetic orthodontic appliances - a review. Annals of Geriatric Education and Medical Sciences. 2018;5:11-14. DOI: 10.18231/2348-7240.2018.0003
7. **Marya A, Venugopal A, Vaid N, Alam MK, Karobari MI.** Essential attributes of clear aligner therapy in terms of appliance configuration, hygiene, and pain levels during the pandemic: a brief review. Pain Research and Management. 2020;2020:6677929. DOI: 10.1155/2020/6677929
8. **Singh D, Sharma VK, Srivastava R, Priyadarshani P, Chaturvedi T.** White spot lesions in clear aligner therapy as compared with multi-bracket system: a systematic review. Journal of Contemporary Orthodontics. 2023;7:165-172. DOI: 10.18231/j.jco.2023.029
9. **Perkelvald A.** Are clear aligners better than the conventional orthodontic fixed appliances? Scientific Journal of Lander College of Arts and Sciences. 2022;15:46-53.
10. **Kesling HD.** The philosophy of the tooth positioning appliance. American Journal of Orthodontics and Oral Surgery. 1945;31(6):297-304. DOI: 10.1016/0096-6347(45)90101-3
11. **Kau CH, Soh J, Christou T, Mangal A.** Orthodontic aligners: current perspectives for the modern orthodontic office. Medicina. 2023;59(10):1773. DOI: 10.3390/medicina59101773
12. **Vlaskalic V, Boyd RL.** Clinical evolution of the Invisalign appliance. Journal of the California Dental Association. 2002;30:769-775. DOI: 10.1080/19424396.2002.12223318
13. **Chang M, Chen CH, Chang C-Y, Lin J, Chang CH, Roberts W.** Introduction to Invisalign® smart technology: attachments design, and recall-checks. Journal of Digital Orthodontics. 2019;54:81-94.
14. **Lombardo L, Martines E, Mazzanti V, Arreghini A, Mollica F, Siciliani G.** Stress relaxation properties of four orthodontic aligner materials: a 24-hour in vitro study. The Angle Orthodontist. 2017;87(1):11-18. DOI: 10.2319/113015-813.1
15. **Dupaix RB, Boyce MC.** Finite strain behavior of poly(ethylene terephthalate) (PET) and poly(ethylene terephthalate)-glycol (PETG). Polymer. 2005;46:4827-4838. DOI: 10.1016/j.polymer.2005.03.083
16. **Freitas MPM.** Aligners, environmental contamination, and the role of orthodontics. The Angle Orthodontist. 2022;92(1):148-149. DOI: 10.2319/1945-7103-92.1.148
17. **Al-Nadawi M, Kravitz ND, Hansa I, Makki L, Ferguson DJ, Vaid NR.** Effect of clear aligner wear protocol on the efficacy of tooth movement. The Angle Orthodontist. 2021;91:157-163. DOI: 10.2319/071520-630.1
18. **Peter E, Monisha J, Ani George S.** Are clear aligners environment friendly? American Journal of Orthodontics and Dentofacial Orthopedics. 2022;161(5):619-620. DOI: 10.1016/j.ajodo.2021.12.012
19. **Gandhi R, Veerasekaran A.** An overview on environmental hazards of clear aligners. Bulletin of Environment, Pharmacology and Life Sciences. 2022;2:519-522.
20. **Horvath T, Kalman M, Szabo T, Roman K, Zsoldos G, Kollar M.** The mechanical properties of polyethylene-terephthalate (PET) and polylactic-acid (PDLLA and PLLA), the influence of material structure on forming. IOP Conference Series: Materials Science and Engineering. 2018;426:012018. DOI: 10.1088/1757-899X/426/1/012018
21. **Venkatesh S, Mahboob S, Govindarajan M, Al-Ghanim KA, Ahmed Z, Al-Mulhm N, et al.** Microbial degradation of plastics: sustainable approach to tackling environmental threats facing big cities of the future. Journal of King Saud University - Science. 2021;33:101362. DOI: 10.1016/j.jksus.2021.101362
22. **Verma R, Vinoda K, Papireddy M, Gowda A.** Toxic pollutants from plastic waste - a review. Procedia Environmental Sciences. 2016;35:701-708. DOI: 10.1016/j.proenv.2016.07.069
23. **Pilapitiya PNT, Ratnayake AS.** The world of plastic waste: a review. Cleaner Materials. 2024;11:100220. DOI: 10.1016/j.clema.2024.100220
24. **Gupta S, Ahluwalia R, Gupta N, Rana S.** Aligners - their properties and disposal. Journal of Pharmaceutical Negative Results. 2022;13. DOI: 10.47750/pnr.2022.13.S06.027
25. **Peter E, Monisha J, George SA.** Bisphenol-A release from thermoplastic clear aligner materials: a systematic review. Journal of Orthodontics. 2023;50:276-286. DOI: 10.1177/14653125231160570
26. **Fenichel P, Chevalier N, Brucker-Davis F.** Bisphenol A: an endocrine and metabolic disruptor. Annales d'Endocrinologie. 2013;74(3):211-220. DOI: 10.1016/j.ando.2013.04.002
27. **Raghavan AS, Sathyanarayana HP, Kailasam V, Padmanabhan S.** Comparative evaluation of salivary bisphenol A levels in patients wearing vacuum-formed and Hawley retainers: an in-vivo study. American Journal of Orthodontics and Dentofacial Orthopedics. 2017;151(3):471-476. DOI: 10.1016/j.ajodo.2016.07.022
28. **Katras S, Ma D, al Dayeh A, Tipton D.** Bisphenol A release from orthodontic clear aligners: an in-vitro study. Recent Progress in Materials. 2021;3(3):1-13. DOI: 10.21926/rpm.2103034

29. **Alhendi A, Khounganian R, Almudhi A, Ahamad SR.** Leaching of different clear aligner systems: an in vitro study. Dentistry Journal. 2022;10(2):27. DOI: 10.3390/dj10020027
30. **Francisco I, Paula AB, Ribeiro M, Marques F, Travassos R, Nunes C, et al.** The biological effects of 3D resins used in orthodontics: a systematic review. Bioengineering. 2022;9(1):15. DOI: 10.3390/bioengineering9010015
31. **Macrì M, D'Albis V, Marciani R, Nardella M, Festa F.** Towards sustainable orthodontics: environmental implications and strategies for clear aligner therapy. Materials. 2024;17(17):4171. DOI: 10.3390/ma17174171
32. **Khanna R, Konyukhov Y, Maslennikov N, Kolesnikov E, Burmistrov I.** An overview of dental solid waste management and associated environmental impacts: a materials perspective. Sustainability. 2023;15(22):15953. DOI: 10.3390/su152215953
33. **Al-Hashimi R.** Plastic waste with clear aligner therapy. British Dental Journal. 2023;235:763. DOI: 10.1038/s41415-023-6573-3
34. **Gussgard AM, Jokstad A.** Polymer waste and pollution in oral healthcare clinics: a systematic review. BDJ Open. 2025;11(1):52. DOI: 10.1038/s41405-025-00342-8
35. **Aligners Globe.** Recycling old aligners | Disposal of clear aligners [Internet]. [cited 2025 Oct 6]. Available from: https://alignersglobe.com/blog/disposal-of-clear-aligners
36. **TerraCycle.** Free recycling programs - press [Internet]. [cited 2026 Apr 20]. Available from: https://www.terracycle.com/en-US
37. **United Nations.** The 17 goals | Sustainable development [Internet]. [cited 2026 Apr 21]. Available from: https://sdgs.un.org/goals