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Knowledge Awareness And Practices Of Aligner Disposal Among Orthodontist, General Dentist And Patients Undergoing Aligner Orthodontic Therapy: A Cross Sectional Study.

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Abstract

Introduction: *Clear Aligners offer a discreet orthodontic treatment alternative, made from materials like PET and TPU, known for their transparency and durability. However, their nonbiodegradable nature raises environmental concerns. This study aims to assess knowledge, awareness and practices regarding Clear Aligner waste among orthodontist general dentist and patients undergoing Clear Aligner therapy to promote effective disposal methods and reduce environmental impact.*

Methodology: *The study included postgraduate orthodontic students, practicing orthodontists, general dentists providing aligners, and patients undergoing aligner therapy. Excluded are those treated with local brands. A 15-item questionnaire assessing knowledge and practices on aligner disposal was validated using face and content validity and administered via Google Sheets to relevant participants.*

Results: *The study analyzed the mean age, gender distribution, and knowledge regarding aligner disposal among orthodontists, general dentists, and patients. Orthodontists had a mean age of 25.9 years, while general dentists averaged 25.1 years, and patients had a broader age range with a mean of 26.4 years. Males predominated in all groups, especially among patients (82.8%). Significant differences in knowledge and awareness were noted, with orthodontists outperforming general dentists and patients in understanding disposal practices. Overall, orthodontists scored highest in knowledge (3.07), awareness (3.48), and practice (2.91), indicating a need for improved education for general dentists and patients.*

Conclusion: *In conclusion, orthodontists, general dentists, and patients differ in aligner disposal knowledge, awareness, and practices. Patients had the lowest grades across all dimensions, whereas orthodontists understood and followed disposal techniques best. Targeted educational initiatives are needed to close the knowledge-practice gap, especially for general dentists and patients. Environmental protection and responsible dental care require better disposal education.*

Keywords: *Aligners, Biomedical Waste Management, Disposal Techniques, Orthodontic Therapy.*

INTRODUCTION

Clear Aligner Therapy (CAT) is a technique for aligning teeth use transparent, unique plastic aligners. The aligners exert mild pressure on the teeth to progressively reposition them as intended. The benefits of CAT encompass the braces being nearly imperceptible, comfortable to wear, and removable for eating and oral hygiene; hence, CAT can address a diverse array of orthodontic concerns.[1]

Adult patients opt for clear aligner treatment despite the increased expense, and orthodontists utilise clear aligners despite their biomechanical constraints due to the aesthetic benefits they provide. The optical characteristics of various clear aligners change due to the composition of the materials employed in their production.[2,3]

Manufacturers utilise a range of materials for the production of orthodontic clear aligners, including polyurethane, polyvinyl chloride (PVC), polyethylene terephthalate glycol (PET-G), polypropylene, polycarbonate, and co-polyester. PETG is extensively utilised due to its superior impact and tear resistance, barrier characteristics, chemical durability, and clarity. Moreover, renowned aligner

manufacturers utilise TPU with enhanced elasticity to provide more predictable orthodontic movements with the application of light and consistent forces. Multi-hybrid materials have been created to enhance the physical qualities of individual materials. [4,5]

These plastics, classified as durable and slow to decompose, provide environmental issues, requiring millennia to disintegrate in natural environments. [6] Polyethylene terephthalate (PET) is characterised by strong crystallinity, which accounts for its exceedingly protracted microbial degradation, spanning hundreds of years.[7] The widespread utilisation of PET, PETG, and other petroleum-derived polymers in transparent aligners exacerbates plastic pollution, impacting ecosystems and contributing to climate change.[8] Plastic pollution, encompassing macro to nanoplastics, jeopardises ecosystems by contaminating freshwater, marine environments, soil, and air, hence imperilling flora and wildlife via the food chain.[9] Patients often utilise several aligners for a duration of 7 to 14 days apiece, which are thereafter disposed of without recycling. [10] The environmental stress caused by excessive plastic accumulation has thus emerged as a significant issue.Between 1950 and 2018, global production of fossil fuel-derived plastics surged dramatically, exceeding 454 million tonnes. 10 Between 1950 and 1980, an astonishing 9.7 billion tonnes of plastics were produced.Each year, around 343 million tonnes of plastic garbage are produced, predominantly from North America, Europe, Central Asia, and the East Asia-Pacific area. [11,12] The indifference towards the production and disposal of plastic has resulted in this extraordinary material being the primary type of garbage in the ecosystem. [11,13] Environmental issues emerge as transparent aligners, primarily made of plastic, decompose gradually in landfills, requiring generations for complete breakdown.[14] Improper disposal presents infection hazards, while incineration emits detrimental cyanide particles, exacerbating air pollution.[15] Nano plastics disseminated into the environment, capable of cellular infiltration, intensify environmental and health hazards.[16]

Our literature review reveals a scarcity of studies validating a questionnaire on knowledge, awareness, and practices about aligner disposal among orthodontists, general dentists, and patients undergoing clear aligner orthodontic therapy.

The current study was necessitated by the necessity to evaluate the knowledge, awareness, and practices of orthodontists, general dentists, and patients undergoing clear aligner orthodontic therapy.

METHODOLOGY

An anonymous cross-sectional electronic study was created using Google Forms, with measures to prevent duplicate submissions through browser cookies. Ethical approval was obtained prior to the study. A pilot e-survey involving 10 orthodontists and 10 general dentists and 10 patients in Mumbai City validated the methodology and questionnaire.

Participants assessed the questionnaire duration for feasibility and data quality, ensuring it was not overly burdensome. Their feedback on question relevance and clarity confirmed the questionnaires focus on significant topics in orthodontics and general dentistry. This pilot study refined the questionnaire, enhancing its validity while excluding pilot participants from the main study to avoid biases. The reporting of the article was based on the Strengthening of the reporting of the observation studies guideline (STROBE)

Demographic Sampling and Study Distribution

Orthodontists, general dentists, and patients receiving clear aligner therapy were considered qualified for inclusion in the study. An online study was done from January 2024 to April 2024 using Google Forms. The Google Form link was randomly sent throughout all important social media sites, including WhatsApp, targeting the intended population. Before participating in the questionnaire, express informed consent, mentioned in the questionnaire form, was obtained from all participants.

Sample Size estimation

The sample size was estimated using Open Epi software keeping confidence interval at 95% and power at 80%. Proportion based sampling technique was employed in the present study which yielded a total sample size of 384. $n=p*q(Za/2/E)^2$

The sample size was further distributed among Orthodontist, General Dentist and Patients undergoing clear aligner therapy.

Statistical Analysis

The data was obtained and entered in microsoft excel version 13. The data was subjected to statistical analysis using IBM Statistical Package for Social Science version 21. For continuous variables Mean and Standard Deviation (SD) was obtained for categorical variable frequency and percentage was obtained.

To evaluate the difference in the proportion pearson's chi square test was applied. To evaluate the difference in the Mean knowledge score, awareness score and practice score between the three groups Analysis of Variance with Post Hoc Tukey's was applied. All the statistical analysis was conducted keeping confidence interval at 95% and ($p<0.05$) was considered to be statistically significant.

RESULTS

Mean Age of the Study Participants

	Study group	N	Minimum	Maximum	Median	Mean	SD
Age	Orthodontist	134	16	46	25	25.9	3.99
	General Dentist	135	18	46	25	25.1	3.65
	Patients	128	18	56	24	26.4	8.82

1. Mean Age of the Study Participants

The age of study participants was slightly different for the three groups. Orthodontists had a mean age of 25.9 years (SD = 3.99), while general dentists were slightly younger with a mean age of 25.1 years (SD = 3.65). Patients had a more varied age distribution with a slightly higher mean age of 26.4 years (SD = 8.82) and ranged from 18 to 56 years, reflecting a wider age profile in patients than among the dental professionals.

Distribution of the Study Participants depending upon the Gender

	Orthodontist (N=134)	General Dentist (N=135)	Patients (N=128)	Total (N=397)	p value
Sex					< 0.0011
Male	82.0 (61.2%)	75.0 (55.6%)	106.0 (82.8%)	263.0 (66.2%)	
Female	52.0 (38.8%)	60.0 (44.4%)	22.0 (17.2%)	134.0 (33.8%)	

2. Gender Distribution of the Study Participants

Gender distribution between the three groups differed significantly ($p < 0.001$). Males dominated all groups, with the highest percentage being from the patient group (82.8%), followed by orthodontists (61.2%), and general dentists (55.6%). Females were underrepresented, especially among the patient group (17.2%), compared to general dentists (44.4%) and orthodontists (38.8%).

Responses of the Study Participants towards Questions based on Knowledge

	Orthodontist (N=134)	General Dentist (N=135)	Patients (N=128)	Total (N=397)	p value
1. What is the recommended way to dispose of used orthodontic aligners?					< 0.0011
Throw them in regular household waste	31.0 (23.1%)	7.0 (5.2%)	33.0 (25.8%)	71.0 (17.9%)	
Biomedical waste disposal	75.0 (56.0%)	77.0 (57.0%)	66.0 (51.6%)	218.0 (54.9%)	
Recycle them with plastic waste	28.0 (20.9%)	30.0 (22.2%)	18.0 (14.1%)	76.0 (19.1%)	
I am not sure	0.0 (0.0%)	21.0 (15.6%)	11.0 (8.6%)	32.0 (8.1%)	
2. What type of waste category do used aligners fall under?					0.0011
Biomedical waste	112.0 (83.6%)	109.0 (80.7%)	90.0 (70.3%)	311.0 (78.3%)	

Hazardous waste	22.0 (16.4%)	11.0 (8.1%)	22.0 (17.2%)	55.0 (13.9%)	
General household waste	0.0 (0.0%)	9.0 (6.7%)	10.0 (7.8%)	19.0 (4.8%)	
E-waste	0.0 (0.0%)	6.0 (4.4%)	6.0 (4.7%)	12.0 (3.0%)	
3. Do clean aligners contain recyclable plastic material?					< 0.0011
Yes, fully recyclable	59.0 (44.0%)	31.0 (23.0%)	51.0 (39.8%)	141.0 (35.5%)	
Partially recyclable	35.0 (26.1%)	36.0 (26.7%)	40.0 (31.2%)	111.0 (28.0%)	
Not recyclable	3.0 (2.2%)	12.0 (8.9%)	11.0 (8.6%)	26.0 (6.5%)	
I am not sure	37.0 (27.6%)	56.0 (41.5%)	26.0 (20.3%)	119.0 (30.0%)	
4. What environmental impact can improper aligner disposal cause?					< 0.0011
Environmental pollution	20.0 (14.9%)	13.0 (9.6%)	34.0 (26.6%)	67.0 (16.9%)	
Spread of infections	13.0 (9.7%)	12.0 (8.9%)	25.0 (19.5%)	50.0 (12.6%)	
Both A and B	100.0 (74.6%)	103.0 (76.3%)	63.0 (49.2%)	266.0 (67.0%)	
None of the above	1.0 (0.7%)	7.0 (5.2%)	6.0 (4.7%)	14.0 (3.5%)	
5. Are there any specific guidelines provided by aligner companies regarding disposal?					< 0.0011
Yes, I know them	65.0 (48.5%)	29.0 (21.5%)	48.0 (37.5%)	142.0 (35.8%)	
Yes, but I am not familiar with them	46.0 (34.3%)	50.0 (37.0%)	40.0 (31.2%)	136.0 (34.3%)	
No, there are no specific guidelines	19.0 (14.2%)	16.0 (11.9%)	18.0 (14.1%)	53.0 (13.4%)	
I am not sure	4.0 (3.0%)	40.0 (29.6%)	22.0 (17.2%)	66.0 (16.6%)	

Pearson's Chi-squared test

3. Responses to Knowledge-Based Questions

Statistically significant differences ($p < 0.001$ for all questions) existed among the groups in answering knowledge-based questions. The largest percentage of orthodontists (56.0%) and general dentists (57.0%) knew that biomedical waste disposal was the recommended option for disposing of used aligners compared to 51.6% of patients. When asked about the waste category, 83.6% of orthodontists and 80.7% of general dentists correctly classified used aligners as biomedical waste, while only 70.3% of patients responded similarly. Regarding recyclability, orthodontists were more likely to state aligners are fully recyclable (44.0%) compared to general dentists (23.0%). On the environmental impact of improper disposal, the majority in all groups recognized both environmental pollution and the spread of infections as consequences. Knowledge of current disposal practices also differed, with 48.5% of orthodontists, but only 21.5% of general dentists and 37.5% of patients, indicating familiarity.

Responses of the Study Participants towards Questions based on Awareness

	Orthodontist (N=134)	General Dentist (N=135)	Patients (N=128)	Total (N=397)	p value
1. Have you ever been informed about proper disposal methods for aligners?					< 0.0011
Yes, by my dentist or orthodontist/aligner provider	65.0 (48.5%)	39.0 (28.9%)	68.0 (53.1%)	172.0 (43.3%)	
Yes, through online resources	28.0 (20.9%)	28.0 (20.7%)	27.0 (21.1%)	83.0 (20.9%)	
No, I have never been informed	41.0 (30.6%)	49.0 (36.3%)	23.0 (18.0%)	113.0 (28.5%)	
I have never thought about it.	0.0 (0.0%)	19.0 (14.1%)	10.0 (7.8%)	29.0 (7.3%)	
2. Do you believe improper aligner disposal has environmental consequences?					< 0.0011
Yes, significantly	105.0 (78.4%)	82.0 (60.7%)	67.0 (52.3%)	254.0 (64.0%)	
Yes, but only minimal impact	29.0 (21.6%)	30.0 (22.2%)	40.0 (31.2%)	99.0 (24.9%)	
No impact at all	0.0 (0.0%)	9.0 (6.7%)	11.0 (8.6%)	20.0 (5.0%)	
I am not sure	0.0 (0.0%)	14.0 (10.4%)	10.0 (7.8%)	24.0 (6.0%)	
3. Have you come across any campaigns or educational materials regarding the safe disposal of aligners?					< 0.0011
Yes, frequently	106.0 (79.1%)	26.0 (19.3%)	43.0 (33.6%)	175.0 (44.1%)	
Yes, but rarely	28.0 (20.9%)	33.0 (24.4%)	42.0 (32.8%)	103.0 (25.9%)	
No, never	0.0 (0.0%)	22.0 (16.3%)	13.0 (10.2%)	35.0 (8.8%)	
I am not sure	0.0 (0.0%)	54.0 (40.0%)	30.0 (23.4%)	84.0 (21.2%)	
4. Are you aware about who should be responsible for educating					< 0.0011
The manufacturer	4.0 (3.0%)	8.0 (5.9%)	30.0 (23.4%)	42.0 (10.6%)	
The dentist or orthodontist	37.0 (27.6%)	36.0 (26.7%)	41.0 (32.0%)	114.0 (28.7%)	
Both manufacturer and dentist	91.0 (67.9%)	84.0 (62.2%)	51.0 (39.8%)	226.0 (56.9%)	
The patient should take the initiative	2.0 (1.5%)	7.0 (5.2%)	6.0 (4.7%)	15.0 (3.8%)	
5. Are you aware about dedicated recycling program for used aligners?					< 0.0011
Yes, definitely	99.0 (73.9%)	83.0 (61.5%)	63.0 (49.2%)	245.0 (61.7%)	
Yes, but only if it is cost effective	35.0 (26.1%)	32.0 (23.7%)	43.0 (33.6%)	110.0 (27.7%)	
No it's unnecessary	0.0 (0.0%)	7.0 (5.2%)	14.0 (10.9%)	21.0 (5.3%)	

I am not sure	0.0 (0.0%)	13.0 (9.6%)	8.0 (6.2%)	21.0 (5.3%)	

Pearson's Chi-squared test

4. Awareness-Based Question Responses

Differences were once more found across all awareness-based items ($p < 0.001$). A higher percentage of patients (53.1%) and orthodontists (48.5%) indicated that they had been educated about disposal practices by a provider, while just 28.9% of general dentists reported the same. Whereas 78.4% of orthodontists felt the inappropriate disposal has serious environmental implications, 60.7% of the general dentists and 52.3% of the patients concurred with the same. Exposure to campaigns or educational content was significantly higher among the orthodontists (79.1%), with a smaller percentage of general dentists (19.3%) and patients (33.6%) experiencing such efforts. A majority of orthodontists (67.9%) and general dentists (62.2%) felt that manufacturers and dentists should be responsible for educating users, whereas fewer patients (39.8%) held this view. Knowledge regarding dedicated recycling programs was also most prevalent among orthodontists (73.9%), followed by general dentists (61.5%) and patients (49.2%).

Responses of the Study Participants towards Questions based on Practices

	Orthodontist (N=134)	**General Dentist (N=135)**	**Patients (N=128)**	**Total (N=397)**	**p value**
1.What is the best protocol a dental clinic can implement for the safe and environmentally responsible disposal or recycling of used clear aligners					< 0.0011
Discard them in regular trash	20.0 (14.9%)	12.0 (8.9%)	44.0 (34.4%)	76.0 (19.1%)	
Use a designated medical waste disposal service	100.0 (74.6%)	110.0 (81.5%)	71.0 (55.5%)	281.0 (70.8%)	
Burn them in an incinerator	14.0 (10.4%)	10.0 (7.4%)	11.0 (8.6%)	35.0 (8.8%)	
Crush and dispose of them in water	0.0 (0.0%)	3.0 (2.2%)	2.0 (1.6%)	5.0 (1.3%)	
2. What should patients do with old aligners after switching to a new set?					< 0.0011
Store them as a backup if advised by their orthodontist	81.0 (60.4%)	55.0 (40.7%)	51.0 (39.8%)	187.0 (47.1%)	
Discard them immediately in household trash	32.0 (23.9%)	20.0 (14.8%)	33.0 (25.8%)	85.0 (21.4%)	
Sometimes, but I eventually discard them	21.0 (15.7%)	19.0 (14.1%)	14.0 (10.9%)	54.0 (13.6%)	
I am not sure what to do with them	0.0 (0.0%)	41.0 (30.4%)	30.0 (23.4%)	71.0 (17.9%)	
3. How do you or your patients usually dispose off your used aligners?					< 0.0011
Throw them in regular trash	0.0 (0.0%)	23.0 (17.0%)	35.0 (27.3%)	58.0 (14.6%)	
Store them for future reference	46.0 (34.3%)	20.0 (14.8%)	29.0 (22.7%)	95.0 (23.9%)	
Dispose them as biomedical waste	60.0 (44.8%)	53.0 (39.3%)	43.0 (33.6%)	156.0 (39.3%)	

Follw manufacturers disposal guidelines	28.0 (20.9%)	39.0 (28.9%)	21.0 (16.4%)	88.0 (22.2%)	
4. Do you sterilize or disinfect used aligners before disposal?					< 0.0011
Yes, always	85.0 (63.4%)	62.0 (45.9%)	60.0 (46.9%)	207.0 (52.1%)	
Sometimes	30.0 (22.4%)	24.0 (17.8%)	36.0 (28.1%)	90.0 (22.7%)	
No, never	19.0 (14.2%)	17.0 (12.6%)	20.0 (15.6%)	56.0 (14.1%)	
I was unaware this was necessary	0.0 (0.0%)	32.0 (23.7%)	12.0 (9.4%)	44.0 (11.1%)	
5. Have you ever inquired about proper disposal of aligners?					< 0.0011
Yes	64.0 (47.8%)	32.0 (23.7%)	52.0 (40.6%)	148.0 (37.3%)	
Yes, but I was not informed about the proper aligner disposal	30.0 (22.4%)	24.0 (17.8%)	37.0 (28.9%)	91.0 (22.9%)	
No	40.0 (29.9%)	56.0 (41.5%)	15.0 (11.7%)	111.0 (28.0%)	
I was unaware this was necessary	0.0 (0.0%)	23.0 (17.0%)	24.0 (18.8%)	47.0 (11.8%)	

Pearson's Chi-squared test

5. Practice-Based Question Responses

There were significant differences in practice-related responses between the groups ($p < 0.001$ for all questions). Most orthodontists (74.6%) and general dentists (81.5%) advocated using designated medical waste disposal services, while 55.5% of patients chose the same. Conversely, 34.4% of patients incorrectly chose discarding aligners in regular trash. Regarding what to do with old aligners, 60.4% of orthodontists recommended storing them as a backup, compared to 40.7% of general dentists and 39.8% of patients. On actual disposal practice, 44.8% of orthodontists discarded aligners as biomedical waste, as opposed to 39.3% of general dentists and 33.6% of patients. Sterilization before disposal was also more prevalent among orthodontists (63.4%) than in other groups. Lastly, 47.8% of orthodontists had asked how to dispose properly, as opposed to 23.7% of general dentists and 40.6% of patients.

Comparison of the Overall Knowledge Score, Awareness Score and Practice Scores of the Participants.

	Groups	**N**	**Mean**	**SD**	**SE**	**F**	**p Value**
Total Knowledge Score	Orthodontist	134	3.07	1.07	0.0925	11.2	0.001
	General Dentist	135	2.59	0.988	0.085		
	Patients	128	2.48	1.157	0.1023		
Total Awareness Score	Orthodontist	134	3.48	1.088	0.094	36.5	0.001
	General Dentist	135	2.33	1.326	0.1141		
	Patients	128	2.28	1.452	0.1284		
Total Practice Score	Orthodontist	134	2.91	1.14	0.0985	15.1	0.001
	General Dentist	135	2.31	1.156	0.0995		
	Patients	128	2.16	1.222	0.108		

6. Comparison of Total Knowledge, Awareness, and Practice Scores

Statistically significant differences were also noted among the three groups of participants in their total knowledge, awareness, and practice scores ($p = 0.001$ for all three). Highest scores were registered by orthodontists in all areas with mean scores of 3.07 (knowledge), 3.48 (awareness), and 2.91 (practice). General dentists reported intermediate scores (2.59, 2.33, and 2.31 respectively) whereas patients

recorded the lowest scores in all the three domains (2.48 for knowledge, 2.28 for awareness and 2.16 for practice), reflective of a clear knowledge-practice gap and highlighting the importance of targeted educational interventions amongst both the professionals and patients.

Pairwise Comparison of the Overall Knowledge Score, Awareness Score and Practice Scores of the Participants.

Tukey Post-Hoc Test – Total Knowledge Score

		Orthodontist	General Dentist	Patients
Orthodontist	Mean difference	—	0.482 ***	0.583 ***
	p-value	—	< .001	< .001
General Dentist	Mean difference		—	0.101
	p-value		—	0.727
Patients	Mean difference			—
	p-value			—

Note. * p < .05, ** p < .01, *** p < .001

Tukey Post-Hoc Test – Total Awareness Score

		Orthodontist	General Dentist	Patients
Orthodontist	Mean difference	—	1.15 ***	1.1964 ***
	p-value	—	< .001	< .001
General Dentist	Mean difference		—	0.0447
	p-value		—	0.958
Patients	Mean difference			—
	p-value			—

Note. * p < .05, ** p < .01, *** p < .001

Tukey Post-Hoc Test – Total Practice Score

		Orthodontist	General Dentist	Patients
Orthodontist	Mean difference	—	0.599 ***	0.746 ***
	p-value	—	< .001	< .001
General Dentist	Mean difference		—	0.147
	p-value		—	0.567
Patients	Mean difference			—
	p-value			—

Note. * p < .05, ** p < .01, *** p < .001

7. Tukey Post-Hoc Test for Pairwise Comparisons

Tukey's post-hoc test indicated statistically significant differences between orthodontists' total knowledge scores and those of general dentists (mean difference = 0.482, $p < 0.001$) and patients (mean difference = 0.583, $p < 0.001$), but the difference between general dentists and patients was not statistically significant. The same trends followed for awareness and practice scores, with orthodontists performing better than the rest in all categories, which highlights their better understanding and implementation of correct aligner disposal practices.

DISCUSSION

A significant environmental issue stems from the estimated 25 million dental aligners that are disposed of in general trash landfills each year.[17] This alarming figure highlights the considerable quantity of discarded aligners that may ultimately reach our waterways. The accumulation of discarded aligners in landfills intensifies environmental repercussions, heightening apprehensions over plastic pollution and the possibility of aligners contributing to marine pollution. Addressing this issue is becoming increasingly essential to mitigate the environmental impacts of aligner disposal. A major environmental issue associated with orthodontic aligners is their role in plastic pollution. These aligners are often manufactured from non-biodegradable plastics such as polyurethane or copolyester. The durability of these materials allows them to remain in the environment for millennia, so intensifying the worldwide plastic waste dilemma.

The frequent replacement of aligners by patients contributes to the environmental load through the accumulation of discarded aligners. The durability and resilience that contribute to the efficacy of aligners in orthodontics also make them resistant to degradation, exacerbating the pollution issue. The disposal of orthodontic aligners poses unique issues. Due to their diminutive size and inconspicuous design, aligners are prone to misplacement, often ending up in landfills and oceans, hence exacerbating the escalating problem of plastic waste. Inadequate disposal adversely impacts the environment and heightens worries regarding the potential entry of microplastics into the food chain, posing dangers to aquatic organisms and ecosystems. It is essential to underscore the significance of appropriate aligner disposal to effectively tackle these environmental issues.[18,19]

The present study was hence aimed to assess the knowledge awareness and practices of the orthodontist, general dentist and patients undergoing clear aligner therapy regarding disposal of the clear aligners

Our study depicted that the study examined the differences in age, gender distribution, knowledge, awareness, and practice regarding aligner disposal among orthodontists, general dentists, and patients. The mean age of orthodontists was 25.9 years, general dentists were slightly younger at 25.1 years, and patients had a broader age range with a mean of 26.4 years. Gender distribution showed a significant male dominance across all groups, particularly among patients (82.8%).

Responses to knowledge-based questions revealed that orthodontists (56.0%) and general dentists (57.0%) had a better understanding of biomedical waste disposal for used aligners compared to patients (51.6%). A majority of orthodontists (83.6%) and general dentists (80.7%) correctly classified used aligners as biomedical waste, while only 70.3% of patients did. Awareness-based responses indicated that more patients (53.1%) and orthodontists (48.5%) had received education on disposal practices compared to general dentists (28.9%). Orthodontists also showed greater awareness of the environmental implications of improper disposal.

In practice-based responses, a significant majority of orthodontists (74.6%) and general dentists (81.5%) recommended using designated medical waste disposal services, while only 55.5% of patients did. The study highlighted a knowledge-practice gap, with orthodontists scoring highest in knowledge (3.07), awareness (3.48), and practice (2.91), while patients scored lowest (2.48, 2.28, and 2.16 respectively). Tukey's post-hoc test confirmed significant differences in total knowledge scores between orthodontists and both general dentists and patients, emphasizing the need for targeted educational interventions to improve understanding and practices related to aligner disposal among all groups.

From the present study we found that our results were in alignment with the reports published by Linjawi et al.[20] observed discrepancies in perspectives, knowledge, and practices about clear aligners among orthodontists, general dentistry practitioners, and other dental specialists. Orthodontists, exhibiting extensive expertise in intricate instances, demonstrated heightened utilisation of clear aligners. Orthodontists commenced a greater number of clear aligner cases than regular dentists, resulting in a significant increase in plastic waste due to the high patient volume treated with clear aligners.

Our analysis revealed a notable disparity in clear aligner disposal procedures between orthodontists and general dentists. The majority of orthodontists selected biomedical waste disposal services, prioritising safer techniques. In contrast, conventional dentists typically disposed of aligners in standard waste. Emphasising the necessity of education, Gupta et al.[21] recommended a strategy wherein patients return worn aligners in a zip lock bag for orthodontic disinfection via UV cleaning or baking soda, thereafter disposing of them in red bags in accordance with biomedical waste regulations.

Kumar et al.[22] described biodegradation as the microbial decomposition of plastics via oxidation or hydrolysis, resulting in the fragmentation of polymer chains. Plastic degradation pathways including photodegradation, hydrolysis, thermo-oxidative degradation, and biodegradation, as noted by Andrady.[23] Clear aligners, which take generations to completely decompose, lead to the accumulation of micro- and nano-sized plastics in waste systems.[24] This study revealed that orthodontists possess a superior awareness of aligner biodegradation compared to general dentists, highlighting the critical necessity to augment general dentists' understanding for prudent aligner use given their prolonged degradation duration.

The mechanical recycling of tiny plastics, including aligners and their packaging, is commonly disfavoured because to the energy expenditure for recycling typically surpassing the material yield.[25] Alternative recycling methods encompass chemical degradation procedures (e.g., glycolysis, hydrolysis, and aminolysis), feedstock recycling (pyrolysis, gasification, and hydrogenation), and biological degradation (microbial degradation utilising bacteria and fungi, and enzymatic degradation).[26,27,28] Glycolysis and gasification are extensively utilised on an industrial scale, whereas other methods remain in the research and development phase but possess considerable potential for sustainable recycling procedures.[26]

Potential strategies to alleviate the ecological impact

Understanding the constraints of aligner systems and applying this insight for appropriate case selection and treatment planning is essential. Creating biodegradable and environmentally sustainable aligner materials is an effective approach to mitigate environmental damage. Enhancing industrial processes to reduce waste and energy consumption at the production level can substantially decrease the overall carbon footprint.[25] Employing direct 3D-printing methodologies for aligner fabrication can diminish material waste and improve manufacturing efficiency.

Placing orders for trays in batches can save waste in situations of tracking errors, particularly in intricate scenarios.[25] Mandatory warnings on aligner packets about their return after use might be engraved and enforced for effective and sustainable disposal.

Clinicians can enhance sustainability initiatives by establishing 'used aligner collecting stations' for both commercially sourced and in-house aligners, promoting ethical disposal procedures.

The key limitation of the study included that Responses were not obtained from participants across diverse geographical regions and therapeutic settings, indicating that the findings are likely to possess limited external validity.

The key strength of the study included face and content validation of the questionnaire there was no improper reporting of the questions performed by the participants or no missing data was observed.

Future recommendation

A comprehensive chemical analysis studying regarding early and bio and ecofriendly degradation of Clear Aligners which will improve the overall environment by decreasing the burden.

To provide critical knowledge regarding clear aligner disposal to general dentist and patients undergoing clear aligner therapy.

Urging to develop Standard Operating procedures for clear aligner disposal.

CONCLUSION

In conclusion, the study reveals significant disparities in knowledge, awareness, and practices regarding aligner disposal among orthodontists, general dentists, and patients. Orthodontists demonstrated the highest levels of understanding and adherence to recommended disposal practices, while patients exhibited the lowest scores across all domains. The findings underscore the necessity for targeted educational interventions to bridge the knowledge-practice gap, particularly for general dentists and patients. Enhanced awareness and education about proper disposal methods are essential to mitigate environmental impacts and promote responsible practices in dental care.

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