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Original Article

Dentistry Section

Comparison of Optical Properties of Clear Aligners Before and After In-vivo Aging

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ABSTRACT

Introduction: There is a rising demand for clear aligners among orthodontic patients and after the expiry of invisalign patent many indigenous aligners have been introduced in several part of the globe including India. The major advantage of the aligners is its invisibility which is attributed to its unique optical properties. The optical properties vary between different aligners and any changes in the optical properties during the clinical use is an important factor to be considered.

Aim: To evaluate and compare the optical properties of three different types of indigenous clear orthodontic aligners before and after in-vivo aging.

Materials and Methods: A prospective clinical study was conducted in the Department of Orthodontics and Dentofacial Orthopaedics, SRM Dental College, Chennai, Tamil Nadu, India, from August to December 2021. Total 36 volunteers participated in the study and were divided into three study groups. In group A subjects had Clearbite aligners (JJ Orthodontics Pvt. Ltd, Thrissur, Kerala), group B had Dentcare clear aligners (Dent Care Dental Lab Pvt. Ltd. Ernakulum, Kerala) and group C had Smile aligners (smile aligners Inc. Mumbai, Maharashtra). Polyvinyl siloxane impression of the maxillary arch was obtained and sent for the fabrication of two sets of clear aligners. One set of aligners were used to measure absorbance and transmittance before in-vivo aging and another set after an intraoral use of 14 days. The measurement of absorbance and transmittance were made at the wavelength range of 400-700 nm using a Shimadzu UV-3600i Plus UV-Vis-NIR spectrophotometer. Intergroup and intragroup comparisons were done using Independent sample t-test and One-way Analysis of Variance (ANOVA).

Results: In all the three groups of aligners evaluated, an increase in the absorbance values was noted at all the wavelengths after in-vivo aging but the increase was not statistically significant (p-value >0.05). Transmittance values of group A samples reduced after in-vivo aging but not significantly, whereas group B values reduced significantly between 400-440 nm (p-value <0.05) and group C values reduced significantly between 400-460 nm and 680-700 nm (p-value <0.05). Intergroup comparison of the mean absorbance and transmittance values of the group A, B and C samples before and after in-vivo aging showed no significant difference at all wavelengths (p-value >0.05).

Conclusion: The absorbance and transmittance values of all the three indigenous aligners did not change significantly after in-vivo aging at most of the evaluated wavelengths.

Keywords: Absorbance, Orthodontic aligners, Polyethylene terephthalate glycol, Polyurethane, Spectrophotometry, Transmittance

INTRODUCTION

Clear aligner therapy is an orthodontic treatment modality in which the patient wears a series of customised removable aligners that gradually moves the teeth to a desired position [1,2]. In the past few decades, there has been a substantial increase in the number of patients seeking clear aligner treatment because of its aesthetic superiority over labial orthodontics and improved comfort than lingual orthodontics [1-4]. Even though, labial and lingual orthodontic appliances provide better biomechanical advantage than clear aligners there has been an increasing trend in the practice of clear aligners across the globe as patients prefer the invisibility it provides [2,5].

Clear aligners offer several advantages including reduced incidence of white spot lesions, caries, gingivitis or periodontal disease compared to patients undergoing fixed orthodontic and are less cumbersome to the orthodontist with substantial reduction in chair side time and total number of visits [5,6].

The concept of using transparent tooth positioner was pioneered by Kesling HD, followed by clear retainers by Pontiz RJ, vacuum formed dental contour appliance by Nahoum HI and the Essix retainers by Sheridan J [5,7-9]. In 1997 Align Technology introduced Invisalign and since then it dominated the world market of clear aligners for two decades and was holding more than 40 patents [10,11]. The patents expired in October 2017. This marked a sudden influx of aligner companies across the globe including India [11].

The absorbance and the transmittance value of the clear aligners is mainly determined by the chemical composition of the materials used in the manufacturing of the aligner [12-14]. From an aesthetic point of view, the colour stability and transparency of orthodontic clear aligners are expected to be stable throughout the treatment [15]. The initial aligners systems used single layer of rigid polyurethane sheets for fabrication of clear aligners. Later Polyvinyl Chloride (PVC), Polyethylene Terephthalate Glycol (PET-G) and elastomer reinforced materials with superior aesthetic and mechanical properties were introduced [16-23]. Each manufacturer use one of these materials for the fabrication of clear aligners but the specific composition is mostly kept as a trade secret, hence the optical and mechanical properties of a clear aligner cannot be concluded based on the generic material used [12-23].

The mechanical properties of various clear aligners have been widely investigated with in-vitro and clinical studies [18,20,24-26]. Though, studies evaluating the optical properties of clear aligners are there in the literature, the studies were done only under laboratory conditions where exact oral environment including masticatory stress, varying oral temperature and pH could not be simulated and there are no published studies on the indigenous aligners manufactured in India [7,13,14,16,25].

Considering this lacunae in the existing literature the current study was designed to evaluate and compare the absorbance, transmittance and staining of three indigenous clear aligners; Clearbite aligners (JJ Orthodontics Pvt. Ltd, Thrissur, Kerala), Dentcare clear aligners (Dent

Care Dental Lab Pvt. Ltd. Ernakulum, Kerala), and Smile aligners, (smile aligners Inc. Mumbai, Maharashtra) after in-vivo aging. The result of this study will help us to determine the aesthetic stability of the three indigenous aligners and also it will help us to understand if these values of clear aligner is a prerequisite for the clear aligner selection.

MATERIALS AND METHODS

A prospective clinical study was conducted in the Department of Orthodontics and Dentofacial Orthopaedics, SRM Dental College, Chennai, Tamil Nadu, India, from August to December 2021. This study was approved by Institutional Review Board and Institutional Ethical Committee (SRMDC/IRB/2019/MDS/No.107). This clinical study is registered in clinical trial registry of India with a registration number CTRI/2021/08/035866.

Sample size calculation: The sample size was calculated using G Power software. The estimated sample size with power of 85% and α error of 0.05% was 36 with 12 in each group. The data for sample size determination was obtained from the study published by Lombardo L et al., in 2015 [7]. Convenience sampling technique was used, 36 volunteers who fulfilled the inclusion criteria and gave informed consent to participate in the study were selected.

Inclusion criteria: Subjects falling in the age group of 18-28 years with Decayed, Missing and Filled Teeth (DMFT) score not more than 2, plaque index not more than 2, without previous history of orthodontic treatment or bruxism were included in the study.

The 36 volunteers were divided into three groups of 12 each in order of their enrollment.

- **Group A (n=12):** Subjects received aligners from Clearbite (JJ Orthodontics Pvt.Ltd, Thrissur, Kerala).
- **Group B (n=12):** Subjects received aligners from Dentcare (Dent Care Dental Lab Pvt.Ltd. Ernakulam, Kerala).
- **Group C (n=12):** Subjects received aligners from Smile aligners (smile aligners Inc. Mumbai, Maharashtra).

Study Procedure

The maxillary impression of the 36 subjects belonging to three study groups were obtained with polyvinyl siloxane material and sent to the respective laboratories for the fabrication of clear aligners. Two sets of aligners with a thickness of 0.8 mm were fabricated from each impression for the clinical study [Table/Fig-1].

One set of aligners from each group were sent to the laboratory for measurement of absorbance and transmittance before in-vivo aging. The next set of aligners were delivered to the study subjects and were instructed to wear the aligners for 24 hours for 14 days except while brushing and eating and to clean the aligner with soft texture tooth brush under running water once in the morning and once at night. The aligners were retrieved at the end of 14 days and transported to the lab for measurement of absorbance and transmittance after in-vivo aging.

The absorbance and transmittance were measured using a Shimadzu UV-3600i Plus UV-Vis-NIR spectrophotometer [Table/Fig-2]. The aligners were sectioned from canine to canine to remove the lingual portion by using a rotating saw before spectrophotometer analysis to expose the labial wall. The aligners were mounted on the holder and placed inside the spectrophotometer for the measurement [Table/Fig-3]. The absorbance and transmittance was measured in the wavelength of 400-700 nm, within the visible spectrum of light at intervals of 20 nm.

STATISTICAL ANALYSIS

Descriptive and Inferential statistics were analysed using Statistical Package for Social Sciences (SPSS) (IBM Corp. Released 2011. IBM SPSS Statistics for Windows Version 20.0. Armonk, NY:IBM Corp). Paired t-test was done for intra group readings and One-way Analysis of Variance (ANOVA) was used to compare the values among the groups.

RESULTS

In all the three groups of aligners evaluated an increase in the absorbance value was noted at all the wavelengths after in-vivo aging in patient's mouth for 14 days but the increase was not statistically significant (p-value >0.05) [Table/Fig-4-6]. The lowest absorbance value of 0.8873±0.006 was recorded in the group C samples at the wavelength of 420 nm and the highest of 1.000±0.000 was recorded in group B samples at 440 nm before aging. But one-way ANOVA comparing the mean absorbance of the samples belonging to the three experimental groups at all wavelengths measured before In-vivo aging showed no significant difference between the values obtained [Table/Fig-7].

The lowest absorbance value of 1.0270±.235 was recorded in the group B samples at the wavelength of 660 nm and the highest of 1.85±0.543 was recorded in group C samples at 440 nm after aging. But an one-way ANOVA comparing the mean absorbance of the group A, B and C samples after in-vivo aging showed no significant difference between the values obtained at all wavelengths [Table/Fig-8].

Transmittance values of group A samples reduced after 14 days of intraoral use but the difference was not statistically significant [Table/Fig-9]. The transmittance values of group B reduced significantly between 400-440 nm above which the reduction was not significant [Table/Fig-10]. In group C, the reduction was significant only at wavelengths between 400-460 nm and 680-700 nm [Table/Fig-11]. The lowest transmittance value of 8.7627±0.032 was recorded in the group A samples at the wavelength of 620 nm and the highest of 11.9787±1.64587 was recorded in group C samples at 420 nm before aging.

The lowest transmittance value of 5.2017±1.56050 was recorded in the group B samples at the wavelength of 420 nm and the highest of 9.5747±5.23260 was recorded in group A samples at 420 nm after aging. The mean transmittance values of the samples from the group A, B and C before aging and after aging were compared using one-way ANOVA test. The comparison did not reveal a significant difference between the mean values at all wavelengths [Table/Fig-12,13].

[Table/Fig-1]: Clear aligners fabricated from the maxillary impressions of the subjects belonging to the three study groups. (Group A-Clearbite aligners, Group B-Dentcare aligners, Group C-Smile aligners). **[Table/Fig-2]:** Shimadzu UV-3600i Plus UV-Vis-NIR spectrophotometer. **[Table/Fig-3]:** Clear aligner positioned in the holder of the spectrophotometer after sectioning from canine to canine. (Images from left to right)

Wavelength (nm)		Mean	Standard deviation	p-value
400	Pretreatment	0.9557	0.05947	0.055
	Post-treatment	1.1920	0.02828	
420	Pretreatment	0.9250	0.06239	0.087
	Post-treatment	1.1835	0.02899	
440	Pretreatment	0.9300	0.06075	0.081
	Post-treatment	1.1640	0.01980	
460	Pretreatment	0.9327	0.05573	0.076
	Post-treatment	1.1330	0.00566	
480	Pretreatment	0.8977	0.00929	**0.007**
	Post-treatment	1.0990	0.01697	
500	Pretreatment	0.9027	0.01106	0.27
	Post-treatment	1.0880	0.02546	
520	Pretreatment	0.9090	0.00872	0.23
	Post-treatment	1.0835	0.02333	
540	Pretreatment	0.9117	0.00850	0.20
	Post-treatment	1.0830	0.02121	
560	Pretreatment	0.9140	0.00872	0.9140
	Post-treatment	1.0865	0.01626	
580	Pretreatment	0.9147	0.00473	0.25
	Post-treatment	1.0795	0.01344	
600	Pretreatment	0.9177	0.00833	0.16
	Post-treatment	1.0900	0.00990	
620	Pretreatment	0.9243	0.00551	0.13
	Post-treatment	1.0885	0.00778	
640	Pretreatment	0.9253	0.00462	0.10
	Post-treatment	1.0895	0.00495	
660	Pretreatment	0.9213	0.00907	**0.036**
	Post-treatment	1.0935	0.00071	
680	Pretreatment	0.9257	0.00115	**0.049**
	Post-treatment	1.0905	0.00071	
700	Pretreatment	0.9267	0.00153	0.073
	Post-treatment	1.0880	0.00141	

[Table/Fig-4]: Paired t-test for comparison of absorbance values before (pretreatment) and after (post-treatment) in-vivo aging at various wavelengths in group A samples.

Wavelength (nm)		Mean	Standard deviation	p-value
400	Pretreatment	0.9867	0.00577	**0.054**
	Post-treatment	1.2900	0.12701	
420	Pretreatment	0.9980	0.00173	0.06
	Post-treatment	1.2970	0.13253	
440	Pretreatment	1.0000	0.00000	0.079
	Post-treatment	1.2867	0.14800	
460	Pretreatment	0.9980	0.00173	0.11
	Post-treatment	1.2560	0.16233	
480	Pretreatment	0.9947	0.00462	0.15
	Post-treatment	1.1663	0.10772	
500	Pretreatment	0.9987	0.00115	0.51
	Post-treatment	1.0720	0.16479	
520	Pretreatment	0.9993	0.00058	0.78
	Post-treatment	1.0377	0.21515	
540	Pretreatment	0.9967	0.00577	0.81
	Post-treatment	1.0330	0.22498	
560	Pretreatment	0.9987	0.00115	0.82
	Post-treatment	1.0317	0.22861	
580	Pretreatment	0.9967	0.00289	0.83
	Post-treatment	1.0280	0.23122	
600	Pretreatment	0.9987	0.00115	0.82
	Post-treatment	1.0317	0.23317	
620	Pretreatment	0.9973	0.00231	0.82
	Post-treatment	1.0310	0.23378	
640	Pretreatment	0.9967	0.00289	0.82
	Post-treatment	1.0300	0.23564	
660	Pretreatment	0.9900	0.00866	0.80
	Post-treatment	1.0270	0.23508	
680	Pretreatment	0.9907	0.00808	0.80
	Post-treatment	1.0287	0.23847	
700	Pretreatment	0.9920	0.00693	0.80
	Post-treatment	1.0273	0.24154	

[Table/Fig-5]: Paired t-test for comparison of absorbance values before and after in-vivo aging in group B samples (Dentcare aligners).
p-value <0.05 was considered as statistically significant

Wavelength (nm)		Mean	Standard deviation	p-value
400	Pretreatment	0.8880	0.00173	0.88
	Post-treatment	1.8453	0.52806	
420	Pretreatment	0.8873	0.00635	0.09
	Post-treatment	1.8547	0.53459	
440	Pretreatment	0.8953	0.00635	0.095
	Post-treatment	1.8500	0.54308	
460	Pretreatment	0.9047	0.00462	0.097
	Post-treatment	1.8327	0.54444	
480	Pretreatment	0.9060	0.00346	0.10
	Post-treatment	1.8027	0.56443	
500	Pretreatment	0.9120	0.00173	0.12
	Post-treatment	1.7727	0.58776	
520	Pretreatment	0.9133	0.00289	0.13
	Post-treatment	1.7647	0.59772	
540	Pretreatment	0.9187	0.00115	0.133
	Post-treatment	1.7663	0.59785	
560	Pretreatment	0.9233	0.00577	0.13
	Post-treatment	1.7710	0.60353	
580	Pretreatment	0.9140	0.00520	0.12
	Post-treatment	1.7707	0.59098	
600	Pretreatment	0.9280	0.00173	0.14
	Post-treatment	1.7770	0.61960	
620	Pretreatment	0.9287	0.00115	0.14
	Post-treatment	1.7790	0.61960	
640	Pretreatment	0.9287	0.00115	0.13
	Post-treatment	1.7810	0.61863	
660	Pretreatment	0.9267	0.00289	0.17
	Post-treatment	1.7807	0.61553	
680	Pretreatment	0.9267	0.00289	0.13
	Post-treatment	1.7863	0.61723	
700	Pretreatment	0.9280	0.00173	0.13
	Post-treatment	1.7867	0.61417	

[Table/Fig-6]: Paired t-test for comparison of absorbance values before and after in-vivo aging in group C samples (Smile aligners).
p-value <0.05 was considered as statistically significant

DISCUSSION

The current study demonstrated no significant difference in the optical properties of the three aligners evaluated before and after in-vivo aging for 14 days as measured by absorbance and transmittance values. They exhibited similar optical properties after in-vivo aging though there was a trend of increased absorbance and reduced transmittance noted in all the three aligners.

Wavelength (nm)		Mean	Standard deviation	95% Confidence Interval for Mean		p-value
				Lower bound	Upper bound	
400	A	0.9557	0.05947	0.8079	1.1034	0.28
	B	0.9867	0.00577	0.9723	1.0010	
	C	0.8880	0.00173	0.8837	0.8923	
	Total	0.9434	0.05294	0.9028	0.9841	
420	A	0.9250	0.06239	0.7700	1.0800	0.28
	B	0.9980	0.00173	0.9937	1.0023	
	C	0.8873	0.00635	0.8716	0.9031	
	Total	0.9368	0.05795	0.8922	0.9813	
440	A	0.9300	0.06075	0.7791	1.0809	0.22
	B	1.0000	0.00000	1.0000	1.0000	
	C	0.8953	0.00635	0.8796	0.9111	
	Total	0.9418	0.05536	0.8992	0.9843	
460	A	0.9327	0.05573	0.7942	1.0711	0.08
	B	0.9980	0.00173	0.9937	1.0023	
	C	0.9047	0.00462	0.8932	0.9161	
	Total	0.9451	0.05003	0.9067	0.9836	
480	A	0.8977	0.00929	0.8746	0.9207	0.079
	B	0.9947	0.00462	0.9832	1.0061	
	C	0.9060	0.00346	0.8974	0.9146	
	Total	0.9328	0.04688	0.8967	0.9688	
500	A	0.9027	0.01106	0.8752	0.9301	0.082
	B	0.9987	0.00115	0.9958	1.0 015	
	C	0.9120	0.00173	0.9077	0.9163	
	Total	0.9378	0.04619	0.9023	0.9733	
520	A	0.9090	0.00872	0.8873	0.9307	0.086
	B	0.9993	0.00058	0.9979	1.0008	
	C	0.9133	0.00289	0.9062	0.9205	
	Total	0.9406	0.04436	0.9065	0.9747	
540	A	0.9117	0.00850	0.8905	0.9328	0.087
	B	0.9967	0.00577	0.9823	1.0110	
	C	0.9187	0.00115	0.9158	0.9215	
	Total	0.9423	0.04119	0.9107	0.9740	
560	A	0.9140	0.00872	0.8923	0.9357	0.085
	B	0.9987	0.00115	0.9958	1.0015	
	C	0.9233	0.00577	0.9090	0.9377	
	Total	0.9453	.04055	0.9142	0.9765	
580	A	0.9147	0.00473	0.9029	0.9264	0.09
	B	0.9967	0.00289	0.9895	1.0038	
	C	0.9140	0.00520	0.9011	0.9269	
	Total	0.9418	0.04134	0.9100	0.9736	
600	A	0.9177	0.00833	0.8970	0.9384	0.088
	B	0.9987	0.00115	0.9958	1.0015	
	C	0.9280	0.00173	0.9237	0.9323	
	Total	0.9481	0.03842	00.9186	0.9776	
620	A	0.9243	0.00551	0.9107	0.9380	0.085
	B	0.9973	0.00231	0.9916	1.0031	
	C	0.9287	0.00115	0.9258	0.9315	
	Total	0.9501	0.03560	0.9227	0.9775	
640	A	0.9253	0.00462	0.9139	0.9368	0.087
	B	0.9967	0.00289	0.9895	1.0038	
	C	0.9287	0.00115	0.9258	0.9315	
	Total	0.9502	0.03497	0.9233	0.9771	
660	A	0.9213	0.00907	0.8988	0.9439	0.28
	B	0.9900	0.00866	0.9685	1.0115	
	C	0.9267	0.00289	0.9195	0.9338	
	Total	0.9460	0.03370	0.9201	0.9719	
680	A	0.9257	0.00115	0.9228	0.9285	0.28
	B	0.9907	0.00808	0.9706	1.0107	
	C	0.9267	0.00289	0.9195	0.9338	
	Total	0.9477	0.03254	0.9227	0.9727	
700	A	0.9267	0.00153	0.9229	0.9305	0.28
	B	0.9920	0.00693	0.9748	1.0092	
	C	0.9280	0.00173	0.9237	0.9323	
	Total	0.9489	0.03254	0.9239	0.9739	

[Table/Fig-7]: One-way ANOVA for comparison of absorbance values between group A, B and C before aging.
p-value <0.05 was considered as statistically significant

The properties of the aligners are hugely dependent on the chemical composition, thickness of the material used and the manufacturing

Wavelength (nm)		Mean	Standard deviation	p-value
400	A	1.1920	0.02828	0.30
	B	1.2900	0.12701	
	C	1.8453	0.52806	
420	A	1.1835	0.02899	0.28
	B	1.2970	0.13253	
	C	1.8547	0.53459	
440	A	1.1640	0.01980	0.27
	B	1.2867	0.14800	
	C	1.8500	0.54308	
460	A	1.1330	0.00566	0.28
	B	1.2560	0.16233	
	C	1.8327	0.54444	
480	A	1.0990	0.01697	0.28
	B	1.1663	0.10772	
	C	1.8027	0.56443	
500	A	1.0880	0.02546	0.22
	B	1.0720	0.16479	
	C	1.7727	0.58776	
520	A	1.0835	0.02333	0.08
	B	1.0377	0.21515	
	C	1.7647	0.59772	
540	A	1.0830	0.02121	0.079
	B	1.0330	0.22498	
	C	1.7663	0.59785	
560	A	1.0865	0.01626	0.082
	B	1.0317	0.22861	
	C	1.7710	0.60353	
580	A	1.0795	0.01344	0.086
	B	1.0280	0.23122	
	C	1.7707	0.59098	
600	A	1.0900	0.00990	0.087
	B	1.0317	0.23317	
	C	1.7770	0.61960	
620	A	1.0885	0.00778	0.085
	B	1.0310	0.23378	
	C	1.7790	0.61960	
640	A	1.0895	0.00495	0.09
	B	1.0300	0.23564	
	C	1.7810	0.61863	

660	A	1.0935	0.00071	0.088
	B	1.0270	0.23508	
	C	1.7807	0.61553	
680	A	1.0905	0.00071	0.085
	B	1.0287	0.23847	
	C	1.7863	0.61723	
700	A	1.0880	0.00141	0.087
	B	1.0876	0.55240	
	C	1.7867	0.61417	

[Table/Fig-8]: One-way ANOVA for comparison of absorbance values between the group A, group B and group C at various wavelengths after in-vivo aging.
p-value <0.05 was considered as statistically significant

Wavelength (nm)		Mean	Standard deviation	p-value
400	Pretreatment	9.9720	0.02425	0.90
	Post-treatment	9.5523	5.40749	
420	Pretreatment	9.9033	0.08372	0.92
	Post-treatment	9.5747	5.23260	
440	Pretreatment	9.7593	0.20842	0.99
	Post-treatment	8.7283	4.97133	
460	Pretreatment	9.5033	0.00289	0.86
	Post-treatment	8.0253	4.60655	
480	Pretreatment	9.4340	0.05716	0.73
	Post-treatment	8.3760	4.18680	
500	Pretreatment	9.2400	0.05196	0.64
	Post-treatment	8.5403	4.11326	
520	Pretreatment	9.0947	0.08198	0.58
	Post-treatment	8.5910	4.05945	
540	Pretreatment	9.0513	0.04446	0.57
	Post-treatment	85670	3.99390	
560	Pretreatment	8.9900	0.00866	0.57
	Post-treatment	8.5190	4.02489	
580	Pretreatment	9.1487	0.04446	0.60
	Post-treatment	84823	3.73066	
600	Pretreatment	8.8533	0.12702	0.56
	Post-treatment	8.4800	4.06286	
620	Pretreatment	8.7627	0.03233	0.53
	Post-treatment	8.4660	3.99707	
640	Pretreatment	8.7760	0.02078	0.54
	Post-treatment	7.4350	3.97223	
660	Pretreatment	8.7773	0.01963	0.56
	Post-treatment	8.3260	3.91358	
680	Pretreatment	8.7967	0.00289	0.55
	Post-treatment	7.3363	3.82669	
700	Pretreatment	8.8040	0.00346	0.55
	Post-treatment	7.3583	3.80245	

[Table/Fig-9]: Paired t-test for comparison of transmittance values before and after in-vivo aging at various wavelengths in group A samples (Clearbite aligners).
p-value <0.05 was considered as statistically significant

Wavelength (nm)		Mean	Standard deviation	p-value
400	Pretreatment	10.0887	0.22632	0.031
	Post-treatment	5.2740	1.52255	
420	Pretreatment	10.0533	0.04619	0.033
	Post-treatment	5.2017	1.56050	
440	Pretreatment	10.0073	0.00635	0.047
	Post-treatment	5.3750	1.81128	
460	Pretreatment	10.0520	0.04503	0.078
	Post-treatment	5.8130	2.18223	
480	Pretreatment	10.1300	0.11258	0.09
	Post-treatment	6.9653	1.81694	
500	Pretreatment	10.0253	0.02194	0.58
	Post-treatment	8.8700	3.14745	
520	Pretreatment	10.0147	0.01270	0.96
	Post-treatment	9.9357	4.84226	
540	Pretreatment	9.9993	0.00058	0.9
	Post-treatment	9.1363	5.22493	
560	Pretreatment	10.0367	0.03175	0.9
	Post-treatment	9.1940	5.33240	
580	Pretreatment	10.0813	0.07044	0.97
	Post-treatment	9.3043	5.47558	
600	Pretreatment	10.0273	0.02367	0.98
	Post-treatment	9.2327	5.47064	
620	Pretreatment	10.0547	0.04734	0.89
	Post-treatment	9.2530	5.50170	
640	Pretreatment	10.0847	0.07332	0.97
	Post-treatment	92913	5.56163	
660	Pretreatment	10.2280	0.19745	0.95
	Post-treatment	9.3547	5.56445	
680	Pretreatment	10.2113	0.18302	0.95
	Post-treatment	9.3453	5.62977	
700	Pretreatment	10.1813	0.15704	0.95
	Post-treatment	9.3980	5.72559	

[Table/Fig-10]: Paired t-test for comparison of transmittance values before and after in-vivo aging at various wavelengths in group B samples (Dentcare aligners).
p-value <0.05 was considered as statistically significant

Wavelength (nm)		Mean	Standard deviation	p-value
400	Pretreatment	10.0490	0.15762	**0.015**
	Post-treatment	5.4937	1.60502	
420	Pretreatment	11.9787	1.64587	**0.012**
	Post-treatment	5.4107	1.47947	
440	Pretreatment	11.8790	1.62851	**0.014**
	Post-treatment	5.6547	1.61682	
460	Pretreatment	11.6663	1.37687	**0.032**
	Post-treatment	6.1140	1.96293	
480	Pretreatment	11.6903	1.29555	0.065
	Post-treatment	6.9300	2.52884	
500	Pretreatment	11.5550	1.31661	0.071
	Post-treatment	7.3810	2.48929	
520	Pretreatment	11.4597	1.24524	0.071
	Post-treatment	7.4337	2.33286	
540	Pretreatment	11.3270	1.15368	0.071
	Post-treatment	7.3340	2.21781	
560	Pretreatment	11.3220	1.09866	0.072
	Post-treatment	7.3090	2.20924	
580	Pretreatment	11.5550	1.31661	0.56
	Post-treatment	7.0933	1.96301	
600	Pretreatment	11.2547	1.05177	0.64
	Post-treatment	7.3107	2.13067	
620	Pretreatment	11.2603	1.02172	0.58
	Post-treatment	7.2517	2.05785	
640	Pretreatment	11.2733	0.99419	0.55
	Post-treatment	7.2083	2.01459	
660	Pretreatment	11.3770	0.89635	0.56
	Post-treatment	7.1510	2.02737	

680	Pretreatment	11.3663	0.90879	**0.049**
	Post-treatment	7.0960	1.92393	
700	Pretreatment	11.3333	0.91985	**0.047**
	Post-treatment	7.0940	1.89514	

[Table/Fig-11]: Paired t-test for comparison of transmittance values before and after in-vivo aging at various wavelengths in group C samples (Smile aligners).
p-value <0.05 was considered as statistically significant

process [7,12,15]. Amorphous polymers like polyurethane, PET-G, polyvinylchloride and polysulfone exhibit high translucency and preferred as aligner materials over crystalline polymers which are highly opaque and unaesthetic [12,15,24,26,27]. All the aligners

Wavelength (nm)		Mean	Standard deviation	95% Confidence Interval for Mean		p-value
				Lower bound	Upper bound	
400	A	9.9720	0.02425	9.9118	10.0322	0.12
	B	10.0887	0.22632	9.5265	10.6509	
	C	10.0490	0.15762	9.6575	10.4405	
	Total	10.0366	0.14766	9.9231	10.1501	
420	A	9.9033	0.08372	9.6954	10.1113	0.23
	B	10.0533	0.04619	9.9386	10.1681	
	C	11.9787	1.64587	7.8901	16.0672	
	Total	10.6451	1.29771	9.6476	11.6426	
440	A	9.7593	0.20842	9.2416	10.2771	0.35
	B	10.0073	0.00635	9.9916	10.0231	
	C	11.8790	1.62851	7.8336	15.9244	
	Total	10.5486	1.29657	9.5519	11.5452	
460	A	9.5033	0.00289	9.4962	9.5105	0.46
	B	10.0520	0.04503	9.9401	10.1639	
	C	11.6663	1.37687	8.2460	15.0867	
	Total	10.4072	1.19275	9.4904	11.3241	
480	A	9.4340	0.05716	9.2920	9.5760	0.29
	B	10.1300	0.11258	9.8503	10.4097	
	C	11.6903	1.29555	8.4720	14.9087	
	Total	10.4181	1.19368	9.5006	11.3357	
500	A	9.2400	0.05196	9.1109	9.3691	0.21
	B	10.0393	0.04002	9.9399	10.1387	
	C	11.5550	1.31661	8.2844	14.8256	
	Total	10.2781	1.21300	9.3457	11.2105	
520	A	9.0947	0.08198	8.8910	9.2983	0.28
	B	10.0173	0.01553	9.9787	10.0559	
	C	11.4597	1.24524	8.3663	14.5530	
	Total	10.1906	1.20624	9.2634	11.1178	
540	A	9.0513	0.04446	8.9409	9.1618	0.28
	B	9.9993	0.00058	9.9979	10.0008	
	C	11.3270	1.15368	8.4611	14.1929	
	Total	10.1259	1.14597	9.2450	11.0068	
560	A	8.9900	0.00866	8.9685	9.0115	0.22
	B	10.0183	0.03175	9.9395	10.0972	
	C	11.3220	1.09866	8.5928	14.0512	
	Total	10.1101	1.15171	9.2248	10.9954	
580	A	9.1487	0.04446	9.0382	9.2591	0.08
	B	10.0440	0.06773	9.8757	10.2123	
	C	11.4330	1.15090	8.5740	14.2920	
	Total	10.2086	1.15171	9.3233	11.0938	
600	A	8.8533	0.12702	8.5378	9.1689	0.079
	B	10.0273	0.02367	9.9685	10.0861	
	C	11.2547	1.05177	8.6419	13.8674	
	Total	10.0451	1.16709	9.1480	10.9422	
620	A	8.7627	0.03233	8.6824	8.8430	0.082
	B	10.0547	0.04734	9.9371	10.1723	
	C	11.2603	1.02172	8.7223	13.7984	
	Total	10.0259	1.19664	9.1061	10.9457	
640	A	8.7760	0.02078	8.7244	8.8276	0.086
	B	10.0490	0.06829	9.8794	10.2186	
	C	11.2733	0.99419	8.8036	13.7430	
	Total	10.0328	1.19076	9.1175	10.9481	
660	A	8.7773	0.01963	8.7286	8.8261	0,087
	B	10.2280	0.19745	9.7375	10.7185	
	C	11.3770	0.89635	9.1503	13.6037	
	Total	10.1274	1.21802	9.1912	11.0637	
680	A	8.7967	0.00289	8.7895	8.8038	0.085
	B	10.1423	0.16095	9.7425	10.5422	
	C	11.3663	0.90879	9.1088	13.6239	
	Total	10.1018	1.20498	9.1755	11.0280	
700	A	8.8040	0.00346	8.7954	8.8126	0.079
	B	10.1813	0.15704	9.7912	10.5714	
	C	11.3333	0.91985	9.0483	13.6184	
	Total	10.1062	1.19181	9.1901	11.0223	

[Table/Fig-12]: One-way ANOVA for comparison of transmittance values among group A, B and C before in-vivo aging.
p-value <0.05 was considered as statistically significant

are not created equal, and those currently on the market differ in terms of their material, thickness and manufacturing process. Alexandropoulos A et al., evaluated the chemical and mechanical properties of three contemporary thermoplastic orthodontic materials (polyurethane, polyester and polyethylene glycol terephthalate) and

Wavelength (nm)		Mean	Standard deviation	p-value
400	A	9.5523	5.40749	0.23
	B	5.2740	1.52255	
	C	5.4937	1.60502	
420	A	9.5747	5.23260	0.23
	B	5.2017	1.56050	
	C	5.4107	1.47947	
440	A	8.7283	4.97133	0.25
	B	5.3750	1.81128	
	C	5.6547	1.61682	
460	A	8.0253	4.60655	0.26
	B	5.8130	2.18223	
	C	6.1140	1.96293	
480	A	8.3760	4.18680	0.28
	B	6.9653	1.81694	
	C	6.9300	2.52884	
500	A	8.5403	4.11326	0.36
	B	8.8700	3.14745	
	C	7.3810	2.48929	
520	A	8.5910	4.05945	0.432
	B	9.9357	4.84226	
	C	7.4337	2.33286	
540	A	85670	3.99390	0.46
	B	9.1363	5.22493	
	C	7.3340	2.21781	
560	A	8.5190	4.02489	0.49
	B	9.1940	5.33240	
	C	7.3090	2.20924	

580	A	8.4823	3.73066	0.51
	B	9.3043	5.47558	
	C	7.0933	1.96301	
600	A	8.4800	4.06286	0.53
	B	9.2327	5.47064	
	C	7.3107	2.13067	
620	A	8.4660	3.99707	0.55
	B	9.2530	5.50170	
	C	7.2517	2.05785	
640	A	7.4350	3.97223	0.56
	B	92913	5.56163	
	C	7.2083	2.01459	
660	A	8.3260	3.91358	0.59
	B	9.3547	5.56445	
	C	7.1510	2.02737	
680	A	7.3363	3.82669	0.60
	B	9.3453	5.62977	
	C	7.0960	1.92393	
700	A	7.3583	3.80245	0.60
	B	9.3980	5.72559	
	C	7.0940	1.89514	

[Table/Fig-13]: One-way ANOVA for comparison of transmittance values between the group A , group B and group C at various wavelengths after in-vivo aging.
p-value <0.05 was considered as statistically significant

observed significant differences in their chemical structure and mechanical properties and therefore anticipated differences in their clinical behaviour [28].

Ideal mechanical properties and chemical stability is a basic requisite of clear aligners. The transparency of the aligner is the major key to their success and popularity [1,2,7,12-14,16-18]. Studies evaluating the optical properties of clear aligners are there in the literature but there are no published studies on the indigenous aligners manufactured in India [Table/Fig-14] [7,13,22,25,29].

Most aligner companies recommend a 14 days consecutive wear of appliance for a minimum of 22 hours per day. The transparency of orthodontic clear aligners should be stable during this period or else the aligners may become less aesthetically appealing during this time period which may be of a clinical concern [12,27]. Clear aligners are exposed to various masticatory stress, salivary enzymes, staining food and beverages, mouthwashes in the oral environment during their two weeks of continuous wear [11,13,22]. These variables are very difficult to simulate in an experimental setup and in-vitro protocols exaggerate the time of exposure of the aligners to the staining agents. Hence, in this study the optical properties of the aligners were evaluated after in-vivo aging for 14 days in patients mouth.

The absorbance and transmittance before and after in-vivo aging and in-vitro staining was measured using a Shimadzu 3600 plus UV-VIS-NIR spectrophotometer using the method recommended by Lombardo L et al., to expose the labial wall [7]. Absorbance is defined as a measure of the capacity of a substance to absorb light of a specified wavelength. Transmittance is the fraction of incident light, at an established wavelength that passes through the material. Greater the transmittance, the more transparent the material and greater the absorbance value, less transparent the material [7].

The result of the current study is in contradiction with the previous study conducted by Lambardo L et al., Liu CL et al., and Bernard G et al., who absorbed significant differences in their optical properties and colour stability of different clear aligner brands [7,25,29]. This may be due to the reason that these studies were conducted under in-vitro conditions where the aligners underwent prolonged exposure to the food stains which were greater than the average time to which the aligners are exposed to stains during intraoral use. Further, the aligners used in these studies differed in their chemical composition, thickness and the method of processing which may affect the optical properties to a great extent.

The clearbite aligners were made from Polyurethane and Polyethylene Terephthalate Glycol (PET-G) where Dentcare aligners and Smile aligners were fabricated from PET-G. Though, the composition of the aligner materials used to fabricate the three aligners evaluated

Author's name and year of publication	Place of study	Type of study	Sample size	Aligners compared	Parameters assessed	Conclusion
Bernard G et al., (2020) [29]	United States of America	In-vitro	100 per group	Invisalign®, Clear Correct® and Minor Tooth Movement®.	Colour changes in the aligners before immersion, after a 12 hrs exposure to instant coffee, red wine and black tea, after a 7 day exposure and after cleaning with Invisalign® cleaning crystals or the Cordless Sonic Cleaner combined with a Retainer Brite® tablet.	The Invisalign® aligners were more prone to pigmentation than the other two with coffee or red wine. Black tea caused more stains on all the three tested brands. Both cleansing methods performed similarly.
Gracco A et al., (2009) [22]	Italy	In-vivo	1 control 11 samples in study group	Invisalign®	Molecular change on the surface of appliance, colour and transparency, surface morphology and composition of surface deposits.	Intraoral conditions influence the optical properties and chemical stability of the aligners.
Zafeiriadis AA et al., (2018) [13]	Greece	In-vivo	30 15 in each group	Vivera® and Essix® C+ thermoplastic retainers	Colour stability of the retainers during intraoral use.	Used retainers exhibited greater colour change than control appliances or teeth only readings, and increased with the duration of use. Both retainers exhibited similar colour stability.
Lombardo L et al., (2015) [7]	Italy	In-vitro	9 samples in each groupm	Invisalign, All-in, f-22 aligner	Absorbance and transmittance before and after aging in-vitro at a constant temperature in artificial saliva supplemented with food colouring for two cycles of 14 days each.	Commercial aligners possess significantly different optical and therefore aesthetic, properties, both as delivered and following aging.
Liu CL et al., (2016) [25]	China	In-vitro	60 in each group	Invisalign, Angelalign and Smartee	Colour stability after staining with coffee.	The Invisalign aligners were more prone than the Angelalign and Smartee aligners to pigmentation. Aligner materials may be improved by considering aesthetic colour stability properties.
Present study, 2022	India	In-vivo	36, 12 in each group	Clearbite, Dentcare, Smile aligners	Absorbance and transmittance before and after intraoral aging for 14 days.	The optical properties of the three aligners evaluated did not significantly differ before and after in-vivo aging in patient's mouth for 14 days. The in-vivo aging does not alter the optical properties of the three aligners evaluated.

[Table/Fig-14]: Studies evaluating the optical properties of clear aligners compared with the current study [7,13,22,25,29].

in the current study differed slightly. The thickness of the material (0.8 mm) and processing methods (thermoforming) were essentially same [30-32].

Gracco A et al., investigated the optical properties of clear aligners before and after intraoral use and noted that the intraoral conditions influence the optical properties and chemical stability of the aligners. [22]. A similar study conducted by Zafeiriadis AA et al., assessed the in-vivo colour alterations of two different clear retainers and observed that used retainers exhibited greater colour change and the colour change increased with time for both materials [13].

The fact that the current study did not demonstrate any such difference may be attributed to the huge improvement in the quality of materials available for aligner fabrication and better methods of aligner processing and finishing available in the current era.

Limitation(s)

This study did not include the dietary variables that affect the staining characteristics of the aligner material.

CONCLUSION(S)

The optical properties of the three aligners evaluated did not significantly differ among themselves as received from the manufactures and after in-vivo aging in patient's mouth for 14 days. The in-vivo aging does not alter the optical properties of the three aligners evaluated. Further in-vitro studies evaluating the staining characters or in-vivo studies including the dietary variables can be conducted for better understanding of the staining characteristics of these aligners.

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