

# Evaluation of the effect of trimline types of clear aligners on esthetic perception using eye-tracking technology and visual analog scale

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**Introduction:** This study aimed to compare the impact of clear aligners with different edge finishes on esthetic perception across various specialties, using eye-tracking technology and the visual analog scale. **Methods:** Three different trimlines are designed at the gingival border: short scallop, straight, and straight extended. The designed aligners were taken in the mouth without a retractor, in a dark environment with a softbox. The prepared images were turned into a survey via the Google Docs document service. The survey questioning esthetic success according to a 5-point Likert scale was sent to the participants via the online channel. Eye tracking will also take place online with Sticky (version 1.4, Tobii Pro Lab; Tobii Technology AB, Danderyd, Sweden), the online form of the Tobii X2-60 eye-tracking software. The data obtained in this study were analyzed using the SPSS software (version 22; IBM, Armonk, NY). Mann-Whitney U test and Kruskal-Wallis H test with Bonferroni correction were used. **Results:** No significant difference was observed among the specialties in terms of scores ( $P > 0.05$ ). In both male and female subjects, all surfaces showed significant differences across trimlines for the number of fixations, number of visits, and time viewed. In addition, Region 2 exhibited significant differences in the number of fixations, number of visits, and time until noticed ( $P < 0.05$ ). In males, region 3 showed significant differences across trimlines for the number of fixations, number of visits, and time viewed ( $P < 0.05$ ). In females, time until noticed also differed significantly ( $P < 0.05$ ). In both male and female subjects, region 4 showed significant differences across trimlines for the number of fixations, number of visits, and time viewed ( $P < 0.05$ ). **Conclusions:** No differences were found among the specialty groups using the conventional survey method. Scalloped and straight trimlines were generally noticed. (Am J Orthod Dentofacial Orthop 2025;168:243-52)

The demand for clear aligners has grown substantially in recent years, driven by an increasing number of adult patients seeking orthodontic treatment.<sup>1</sup> The concept of clear aligners was first

introduced by Kesling in the early 1940s.<sup>2</sup> The prevalence of clear aligners has markedly increased, propelled by innovations in dental materials and 3-dimensional technology.<sup>3</sup> Clear aligners have several benefits, such as an esthetically appealing and comfortable treatment experience, improved dental cleanliness, less discomfort relative to traditional orthodontic equipment, fewer and briefer consultations, and a reduced necessity for emergency visits.<sup>4,5</sup> Collectively, these factors suggest that esthetic considerations play a crucial role in patients' choice of orthodontic treatment, particularly among those seeking to conceal archwires while smiling.<sup>6</sup>

Clear aligners, such as any emerging technology, present certain limitations and challenges. One significant disadvantage is the increased elasticity of the material around the gingival borders, which makes it prone to deformation and strain, thereby compromising its effectiveness, particularly in achieving orthodontic torque. To achieve torque, force must be applied at both the incisal

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The ethics committee of Istanbul Kent University approved the study protocol (No. 2024/03).

The data are protected on an encrypted computer and can be accessed when needed.

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edge and the gingival border of the aligners; otherwise, just a tipping movement would occur.<sup>7</sup> The design of the gingival edge is critical in determining the aligner's performance, yet it is often discussed in the literature only in terms of its general classification.<sup>8</sup> In the study conducted by Cowley et al<sup>7</sup> categorized gingival edge finishes into 3 types: scalloped (conforming to the natural contour of the gingiva), straight (aligned with the gingival zenith), and extended (positioned 2 mm above the gingival zenith). These design variations influence plaque retention and aligner fit, which in turn affects treatment predictability.<sup>8</sup> Elshazly et al<sup>9</sup> assessed force transmission resulting from trimming line design and extension on aligners, discovering that the straight extended design of the aligner's trimming line exhibited superior uniformity in force transfer and stress distribution across the surface when compared with scalloped, scalloped extended, and straight designs. There are studies in the literature on the effects of the gingival edge design of aligners on tooth movement and periodontal health.<sup>7-10</sup>

Numerous studies in the literature evaluate clear aligner treatments against other orthodontic techniques for esthetics.<sup>11-14</sup> Thai et al<sup>14</sup> used eye-tracking technology to compare esthetic outcomes between aligners with front and posterior attachments and esthetic braces, revealing that patients with minimal attachments spent the least time observing them. An examination of the literature reveals an absence of studies on the impact of various gingival edge designs in aligners on esthetic perception. This study aimed to critically examine the impact of clear plates with varying edge finishes on esthetic perception across subjects from diverse occupations, using eye-tracking technology and a visual analog scale.

## MATERIAL AND METHODS

In this study, 2 volunteers—1 adult female and 1 male participant—were randomly selected. Both participants were free of any malocclusions. Intraoral records were captured using an iTero intraoral scanner (Align Technologies, San Jose, Calif). Three-dimensional models were generated and printed with Softflex W2P (W2P Engineering GmbH, Vienna, Austria) and fabricated using CA Pro (Scheu-Dental GmbH, Iserlohn, Germany). Aligners with a thickness of 0.6 mm were subsequently fabricated using the Biostar system (Scheu-Dental GmbH). Three distinct gingival edge trimlines were designed for the aligners: straight, scallop, and extended straight (Fig, A-F).

The aligners were photographed intraorally without the use of a retractor in a controlled dark environment, using a softbox to ensure consistent lighting and

positioning. A single photographer (S.Ö.) captured the images using a Nikon D5600 18-55 VR AF-P DSLR camera (Nikon Corporation, Tokyo, Japan). The images were then transferred to a computer and converted into a survey format using Google Docs. The esthetic success of the aligners was assessed using a 5-point Likert scale. The survey was distributed to participants via an online platform, and responses were collected through the same system (Fig). Eye tracking was performed online using Sticky (version 1.4, Tobii Pro Lab; Tobii Technology AB, Danderyd, Sweden), the online version of the Tobii X2-60 eye-tracking system (Fig).

Participants were positioned at eye level, approximately 60–65 cm from the computer screen, and instructed to track a ball moving across the screen using the online version of the Tobii system, which was calibrated to their device. After calibration, digital images were displayed on the screen for 5 seconds. Data were collected for each image, including the location and timing of the initial fixation, total fixation duration, total number of picture returns, and overall time spent on the image. Fixations were defined as instances in which the eye remained stationary for  $\geq 80$  milliseconds.

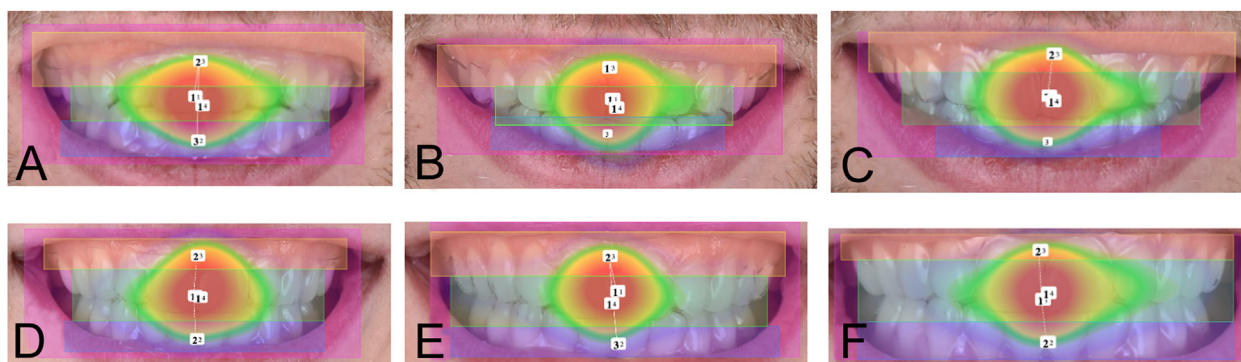
A power analysis was conducted using the G\*Power software (version 3.1.9.4; Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany) based on Thai et al.<sup>14</sup> The effect size was set to 0.25, with an  $\alpha$  of 0.05 and a power ( $1 - \beta$ ) of 0.85. The analysis indicated that 180 participants would be required for our investigation. Participants with visual or cognitive impairments will be excluded from the study. The study will involve 3 survey groups: orthodontists and orthodontic students ( $n = 60$ ), dental faculty students ( $n = 60$ ), and laypersons ( $n = 60$ ).

## Statistical analysis

The data collected in this study were analyzed using SPSS software (version 22; IBM, Armonk, NY). Because of the nonnormal distribution of the data, the Mann-Whitney U test was applied for pairwise comparisons, whereas the Kruskal-Wallis H test with Bonferroni correction was used for comparisons across  $\geq 3$  groups. A significance level of 0.05 was set, with  $P < 0.05$  indicating statistical significance and  $P > 0.05$  suggesting no statistically significant difference.

## RESULTS

The study protocol was approved by the Ethics Committee of Istanbul Kent University (2024/03). A total of 180 participants were included in the study: 27 males and 33 females from the layperson group, 36 males and 24 females from the dental student group, and 15



**Fig.** A, Male/straight trimline; B, Male/scallop trimline; C, Male/extended trimline; D, Female/straight trimline; E, Female/scallop trimline; F, Female/extended trimline. 1, all region; 2, maxillary gingival line region; 3, mandibular gingival line region; 4, incisal edge region.

males and 45 females from the orthodontist group. Among the participants, 82.2% were aged between 20 and 30 years, 17.2% were aged between 30 and 40 years, and 0.6% were aged between 40 and 50 years. No significant differences in scores were observed among the different specialty groups ( $P > 0.05$ ) (Table I). After completing the survey, all participants participated in an eye-tracking assessment using the Sticky software developed by Tobii. The software analyzed data from subjects with moderate to high calibration values, excluding 21 participants with low calibration values. The eye-tracking results are visually represented in the heatmap shown in the Figure.

In region 1 (Table II), male subjects in group 1 exhibited significantly lower values for the number of fixations and time viewed (in seconds) than males in groups 2 and 3 ( $P < 0.05$ ). The values for the number of visits in group 1 were significantly greater than those in groups 2 and 3 ( $P < 0.05$ ). In region 2 (Table II), group 1 exhibited significantly higher values for the number of fixations than those in groups 2 and 3, whereas group 2 also demonstrated significantly higher values than group 3 ( $P < 0.05$ ). Group 3 demonstrated significantly lower values for the number of visits than groups 1 and 2 ( $P < 0.05$ ). Group 3 exhibited significantly higher time until noticed (in seconds) values than groups 1 and 2 ( $P < 0.05$ ).

In region 1 (Table II), female subjects in group 2 exhibited significantly lower values for the number of fixations and time viewed (in seconds) than those in groups 1 and 3. The number of visits in group 3 was significantly greater than in groups 1 and 2 ( $P < 0.05$ ). In region 2, group 3 exhibited significantly higher values for the number of fixations and number of visits when than groups 1 and 2. The values for the time until noticed (in seconds) in group 1 were significantly greater than those in groups 2 and 3 ( $P < 0.05$ ).

**Table I.** Evaluation of the responses given by subjects in each of the 3 specialty groups to the visual analog scale questionnaire

Groups	n	Mean ± SD	Kruskal-Wallis H	
			H value	P value <sup>†</sup>
<b>Male/straight trimline</b>				
Laypeople	60	3.00 ± 1.13	1.7	0.431
Dentistry students	60	2.75 ± 0.93		
Orthodontists	60	2.93 ± 0.84		
<b>Male/scalloped trimline</b>				
Laypeople	60	3.65 ± 1.09	4.9	0.085
Dentistry students	60	3.33 ± 0.95		
Orthodontists	60	3.38 ± 0.92		
<b>Male/extended trimline</b>				
Laypeople	60	3.43 ± 1.09	4.3	0.118
Dentistry students	60	3.10 ± 0.99		
Orthodontists	60	3.23 ± 0.93		
<b>Female/straight trimline</b>				
Laypeople	60	3.78 ± 1.15	3.0	0.219
Dentistry students	60	3.47 ± 1.11		
Orthodontists	60	3.70 ± 0.83		
<b>Female/scalloped trimline</b>				
Laypeople	60	3.57 ± 1.09	2.4	0.308
Dentistry students	60	3.32 ± 0.95		
Orthodontists	60	3.50 ± 0.83		
<b>Female/extended trimline</b>				
Laypeople	60	3.52 ± 1.13	0.01	0.982
Dentistry students	60	3.53 ± 0.98		
Orthodontists	60	3.55 ± 0.89		

SD, standard deviation.

<sup>†</sup> $P < 0.05$  are statistically significant; thus, all  $P$  values presented in this table are not significant.

In region 3 (Table III), group 3 exhibited significantly lower values for the number of fixations, time until noticed (in seconds), and time viewed (in seconds) than groups 1 and 2 ( $P < 0.05$ ). In region 4, group 3 exhibited significantly higher values for the number of fixations

**Table II.** Evaluation of eye-tracking results on male and female subjects on all surfaces in the Sticky by Tobii application

Variables	n	Male				Female			
		Mean ± SD	Kruskall-Wallis H			Mean ± SD	Kruskall-Wallis H		
			H value	P value <sup>†</sup>	Post-hoc test		H value	P value <sup>†</sup>	Post-hoc test
<b>Region 1 (all surfaces)</b>									
No. of clicks									
1: Scalloped	159	0.00 ± 0.00	3.50	0.173	–	0.01 ± 0.00	2.00	0.368	–
2: Straight	159	0.02 ± 0.24				0.00 ± 0.00			
3: Extended	159	0.04 ± 0.30				0.00 ± 0.00			
No. of fixations									
1: Scalloped	159	77.2 ± 12.9	7.24	0.027	1-2	82.0 ± 10.2	172.10	0.0001	2-1
2: Straight	159	80.7 ± 11.1			1-3	69.1 ± 8.7			2-3
3: Extended	159	79.3 ± 11.9				80.0 ± 11.1			
No. of visits									
1: Scalloped	159	4.01 ± 2.68	9.54	0.008	1-2	2.83 ± 2.14	13.40	0.001	3-1
2: Straight	159	3.09 ± 2.06			1-3	2.36 ± 1.67			3-2
3: Extended	159	3.44 ± 2.42				3.23 ± 2.22			
Time until noticed (s)									
1: Scalloped	159	0.052 ± 0.141	0.631	0.729	–	0.039 ± 0.073	1.16	0.559	–
2: Straight	159	0.030 ± 0.062				0.041 ± 0.189			
3: Extended	159	0.038 ± 0.093				0.044 ± 0.126			
Time viewed (s)									
1: Scalloped	159	5.128 ± 0.841	10.27	0.006	1-2	5.489 ± 0.641	180.20	0.0001	2-1
2: Straight	159	5.391 ± 0.672			1-3	4.602 ± 0.547			2-3
3: Extended	159	5.288 ± 0.766				5.352 ± 0.725			
<b>Region 2<sup>‡</sup></b>									
No. of clicks									
1: Scalloped	159	0.00 ± 0.00	2.00	0.368		0.00 ± 0.00	0	1.000	–
2: Straight	159	0.01 ± 0.16				0.00 ± 0.00			
3: Extended	159	0.00 ± 0.00			–	0.00 ± 0.00			
No. of fixations									
1: Scalloped	159	16.3 ± 15.9	23.07	0.0001	1-2	8.4 ± 12.1	13.2	0.001	3-1
2: Straight	159	13.2 ± 14.1			1-3	9.8 ± 12.9			3-2
3: Extended	159	9.3 ± 12.1			2-3	13.5 ± 16.5			
No. of visits									
1: Scalloped	159	5.32 ± 4.24	21.20	0.0001	3-1	3.10 ± 3.56	13.9	0.001	3-1
2: Straight	159	4.83 ± 3.98			3-2	3.36 ± 3.12			3-2
3: Extended	159	3.53 ± 3.89				4.47 ± 3.91			
Time until noticed (s)									
1: Scalloped	159	1.041 ± 1.315	20.10	0.0001	3-1	1.564 ± 1.552	6.18	0.045	1-2
2: Straight	159	1.300 ± 1.460			3-2	1.246 ± 1.345			1-3
3: Extended	159	1.790 ± 1.572				1.191 ± 1.465			
Time viewed (s)									
1: Scalloped	159	1.204 ± 1.040	6.02	0.051	–	0.793 ± 0.875	5.16	0.076	–
2: Straight	159	1.041 ± 0.938				0.848 ± 0.878			
3: Extended	159	0.880 ± 0.836				1.061 ± 1.104			

SD, standard deviation.

<sup>†</sup>P < 0.05 as statistically significant; <sup>‡</sup>Includes the maxillary gingival line.

and time viewed (in seconds) than groups 1 and 2 (P < 0.05). After analysis of the number of visits, group 3 exhibited significantly lower values than in groups 1 and 2 (P < 0.05). In region 3 (Table III), group 1 exhibited significantly higher values for the number of fixations, the number of visits, and time viewed (in seconds) than groups 2 and 3, whereas group 2 showed significantly higher values than group 3 (P < 0.05). The time until

noticed (in seconds) values in group 3 were significantly greater than those in groups 1 and 2 (P < 0.05).

In region 4, group 3 exhibited a significantly higher number of fixations values than groups 1 and 2; in addition, group 1 had higher values than group 2 (P < 0.05). In contrast, the values for the number of visits and time viewed (in seconds) in group 2 were significantly lower than those in groups 1 and 3 (P < 0.05). Statistical data

**Table III.** Evaluation of eye-tracking results on regions 3 and 4 in the Sticky by Tobii application for male and female subjects across participants from each group

Variables	n	Male				Female			
		Mean ± SD	Kruskall-Wallis H			Mean ± SD	Kruskall-Wallis H		
			H value	P value <sup>†</sup>	Post-hoc test		H value	P value <sup>†</sup>	Post-hoc test
<b>Region 3<sup>‡</sup></b>									
No. of clicks									
1: Scalloped	159	0.00 ± 0.00	2.00	0.368	–	0.00 ± 0.00	0.00	1.000	–
2: Straight	159	0.00 ± 0.24				0.00 ± 0.00			
3: Extended	159	0.01 ± 0.08				0.00 ± 0.00			
No. of fixations									
1: Scalloped	159	25.6 ± 19.4	25.56	0.0001	3-1	23.7 ± 21.0	35.32	0.0001	1-2
2: Straight	159	28.7 ± 20.5			3-2	14.9 ± 14.8			1-3
3: Extended	159	18.5 ± 18.7				10.8 ± 13.5			2-3
No. of visits									
1: Scalloped	159	6.40 ± 3.86	19.90	0.008	3-1	5.75 ± 4.13	19.87	0.0001	1-2
2: Straight	159	6.43 ± 3.74			3-2	4.06 ± 3.57			1-3
3: Extended	159	4.72 ± 3.72				3.95 ± 3.52			
Time until noticed (s)									
1: Scalloped	159	0.851 ± 1.145	4.70	0.729	–	0.929 ± 1.268	16.55	0.0001	3-1
2: Straight	159	0.786 ± 1.056				1.083 ± 1.269			3-2
3: Extended	159	1.101 ± 1.219				1.451 ± 1.454			
Time viewed (s)									
1: Scalloped	159	1.857 ± 1.206	17.02	0.006	3-1	1.763 ± 1.351	36.26	0.0001	1-2
2: Straight	159	2.019 ± 1.316			3-2	1.230 ± 0.944			1-3
3: Extended	159	1.452 ± 1.209				0.887 ± 1.454			2-3
<b>Region 4<sup>§</sup></b>									
No. of clicks									
1: Scalloped	159	0.00 ± 0.00	1.02	0.606	–	0.00 ± 0.00	2.00	0.368	–
2: Straight	159	0.01 ± 0.08				0.00 ± 0.00			
3: Extended	159	0.01 ± 0.16				0.00 ± 0.00			
No. of fixations									
1: Scalloped	159	34.0 ± 18.4	52.2	0.0001	3-1	46.8 ± 20.7	46.03	0.0001	3-1
2: Straight	159	32.5 ± 17.1			3-2	39.2 ± 17.5			3-2
3: Extended	159	47.8 ± 20.9				54.8 ± 20.6			1-2
No. of visits									
1: Scalloped	159	8.08 ± 3.66	13.90	0.001	3-1	7.69 ± 3.28	24.50	0.0001	2-1
2: Straight	159	8.82 ± 3.42			3-2	6.26 ± 2.54			2-3
3: Extended	159	7.50 ± 3.14				7.70 ± 3.14			
Time until noticed (s)									
1: Scalloped	159	0.337 ± 0.712	4.40	0.109	–	0.279 ± 0.720	5.19	0.074	–
2: Straight	159	0.263 ± 0.520				0.258 ± 0.625			
3: Extended	159	0.238 ± 0.559				0.165 ± 0.409			
Time viewed (s)									
1: Scalloped	159	2.262 ± 1.215	51.90	0.0001	3-1	3.146 ± 1.357	45.80	0.0001	2-1
2: Straight	159	2.189 ± 1.112			3-2	2.628 ± 1.134			2-3
3: Extended	159	3.183 ± 1.373				3.658 ± 1.369			

SD, standard deviation.

<sup>†</sup>P < 0.05 as statistically significant; <sup>‡</sup>Mandibular gingival region; <sup>§</sup>Incisal edge region.

for various regions of the 3 trimlines concerning male and female participants are displayed in [Tables IV](#) and [V](#).

## DISCUSSION

Numerous studies have compared clear aligner treatments with alternative orthodontic methods, particularly in terms of esthetics.<sup>11-14</sup> These studies

used eye-tracking technology to assess the esthetic differences between aligners with anterior and posterior attachments and esthetic braces. The results indicated that participants spent the least amount of time focusing on aligners with minimal attachments, followed by ceramic braces, and then anterior and posterior attachments. However, there is a notable gap in the

**Table IV.** The evaluation of different regions of the 3 trimlines in male participants

Variables	n	Male scallop trimline				Male straight trimline				Male extended trimline			
		Mean ± SD	Kruskall-Wallis H test			Mean ± SD	Kruskall-Wallis H test			Mean ± SD	Kruskall-Wallis H test		
			H value	P value <sup>†</sup>	Post-hoc test		H value	P value <sup>†</sup>	Post-hoc test		H value	P value <sup>†</sup>	Post-hoc test
No. of clicks													
Region 1	159	0.00 ± 0.00	0	1.000	–	0.02 ± 0.24	1.00	0.80	–	0.04 ± 0.30	3.83	0.281	–
Region 2	159	0.00 ± 0.00				0.01 ± 0.16				0.00 ± 0.00			
Region 3	159	0.00 ± 0.00				0.00 ± 0.00				0.01 ± 0.08			
Region 4	159	0.00 ± 0.00				0.01 ± 0.08				0.01 ± 0.16			
No. of fixations					1-2								1-21-3
Region 1	159	77.20 ± 12.86	369.30	0.0001	1-3	80.69 ± 11.11	399.50	0.0001	1-3	79.25 ± 11.93	445.09	0.0001	1-4
Region 2	159	16.33 ± 15.91			1-4	13.16 ± 14.06			1-4	9.35 ± 12.14			4-2
Region 3	159	25.57 ± 19.41			2-3	28.70 ± 20.52			2-3	18.49 ± 18.72			4-3
Region 4	159	34.00 ± 18.38			2-4	32.50 ± 17.10			2-4	47.81 ± 20.90			2-3
No. of visits					4-1								
Region 1	159	4.01 ± 2.68	97.50	0.0001	4-2	3.09 ± 2.06	186.20	0.0001	4-2	3.44 ± 2.42	134.52	0.0001	4-1
Region 2	159	5.32 ± 4.24			4-3	4.83 ± 3.98			4-3	3.53 ± 3.89			4-2
Region 3	159	6.40 ± 3.86			3-1	6.43 ± 3.74			3-1	4.72 ± 3.72			4-3
Region 4	159	8.08 ± 3.66			3-2	8.82 ± 3.42			3-2	7.50 ± 3.14			
Time until noticed (s)					1-2								1-21-3
Region 1	159	0.05 ± 0.14	156.80	0.0001	1-3	0.03 ± 0.06	203.90	0.0001	1-3	0.04 ± 0.09	232.21	0.0001	1-4
Region 2	159	1.04 ± 1.32			1-4	1.30 ± 1.46			1-4	1.79 ± 1.57			2-3
Region 3	159	0.85 ± 1.15			2-3	0.79 ± 1.06			2-3	1.10 ± 1.22			2-4
Region 4	159	0.34 ± 0.71			2-4	0.26 ± 0.52			2-4	0.24 ± 0.56			3-4
Time viewed (s)					1-2								1-21-3
Region 1	159	5.13 ± 0.84	355.40	0.0001	1-2	5.39 ± 0.67	382.30	0.0001	1-3	5.29 ± 0.77	392.44	0.0001	1-4
Region 2	159	1.20 ± 1.04			1-3	1.04 ± 0.94			1-4	0.88 ± 0.84			4-2
Region 3	159	1.86 ± 1.21			1-4	2.02 ± 1.32			2-3	1.45 ± 1.21			4-3
Region 4	159	2.26 ± 1.22				2.19 ± 1.11			2-4	3.18 ± 1.37			2-3

SD, standard deviation.

<sup>†</sup>P < 0.05 as statistically significant.

**Table V.** The evaluation of different regions of the 3 trimlines in female participants

Variables	n	Female scallop trimline				Female straight trimline				Female extended trimline			
		Mean ± SD	Kruskall-Wallis H test			Mean ± SD	Kruskall-Wallis H test			Mean ± SD	Kruskall-Wallis H test		
			H value	P value <sup>†</sup>	Post-hoc test		H value	P value <sup>†</sup>	Post-hoc test		H value	P value <sup>†</sup>	Post-hoc test
No. of clicks													
Region 1	15	0.01 ± 0.08	2.03	0.572		0.00 ± 0.00	0	1.000		0.00 ± 0.00	0	1.000	
Region 2	159	0.00 ± 0.00				0.00 ± 0.00				0.00 ± 0.00			
Region 3	159	0.00 ± 0.00				0.00 ± 0.00				0.00 ± 0.00			
Region 4	159	0.01 ± 0.08			-	0.00 ± 0.00			-	0.00 ± 0.00			-
No. of fixations					1-2 1-3				1-2 1-3				1-2
Region 1	159	82.04 ± 10.24	451.1	0.0001	1-4	69.06 ± 8.72	444.6	0.0001	1-4	80.01 ± 11.11	457.4	0.0001	1-3
Region 2	159	8.36 ± 12.12			2-3	9.77 ± 12.88			4-2	13.48 ± 16.46			1-4
Region 3	159	23.71 ± 21.02			2-4	14.86 ± 14.84			4-3	10.81 ± 13.54			4-3
Region 4	159	46.76 ± 20.67			3-4	39.24 ± 17.48			3-2	54.84 ± 20.58			4-2
No. of visits					4-1				4-1				
Region 1	159	2.83 ± 2.14	176.3	0.0001	4-2	2.36 ± 1.67	139.6	0.0001	4-2	3.23 ± 2.22	17.2	0.0001	
Region 2	159	3.10 ± 3.56			4-3	3.36 ± 3.12			4-3	4.47 ± 3.91			4-1
Region 3	159	5.75 ± 4.13			3-1	4.06 ± 3.57			3-1	3.95 ± 3.52			4-2
Region 4	159	7.69 ± 3.28			3-2	6.26 ± 2.54			3-2	7.70 ± 3.14			4-3
Time until noticed (s)					1-2				1-2				1-2
Region 1	159	0.04 ± 0.07	201.3	0.0001	1-3 1-4	0.04 ± 0.19	189.4	0.0001	1-3	0.04 ± 0.13	245.09	0.0001	1-3
Region 2	159	1.56 ± 1.55			2-3	1.25 ± 1.35			1-4	1.19 ± 1.47			1-4
Region 3	159	0.93 ± 1.27			2-4	1.08 ± 1.27			2-3	1.45 ± 1.45			4-3
Region 4	159	0.28 ± 0.72			3-4	0.26 ± 0.62			2-4	0.16 ± 0.41			4-2
Time viewed (s)					1-2 1-3				1-2 1-3				1-2
Region 1	159	5.49 ± 0.64	404.8	0.0001	1-4	4.60 ± 0.55	403.4	0.0001	1-4	5.35 ± 0.72	420.33	0.0001	1-3
Region 2	159	0.79 ± 0.87			2-3	0.85 ± 0.88			2-3	1.06 ± 1.10			1-4
Region 3	159	1.76 ± 1.35			4-2	1.23 ± 0.94			2-4	0.89 ± 0.93			4-3
Region 4	159	3.15 ± 1.36			4-3	2.63 ± 1.13			3-4	3.66 ± 1.37			4-2

SD, standard deviation.

<sup>†</sup>P < 0.05 as statistically significant.

literature regarding the impact of different gingival edge designs in aligners on esthetic perception. This gap highlights the need for further research to explore how variations in aligner design may influence patients' esthetic evaluations and preferences.

Eye-tracking technology in dentistry has gained increasing attention as a tool for analyzing patient behavior, attention, and perception during clinical procedures. Its application aims to optimize clinical performance by providing real-time feedback on eye movements during treatment.<sup>15</sup> Moreover, eye-tracking technology has been employed to evaluate dentist-patient communication effectiveness and assess treatment satisfaction.<sup>16</sup> Unlike previous studies, this research does not focus on treatment outcomes but rather examines the impact of orthodontic treatments on patients' social lives during the treatment process, with a particular emphasis on the patient experience at different stages of treatment.

The methodology of this study incorporated both the widely used survey method in the orthodontic literature and an eye-tracking system to collect quantitative data. The eye-tracking data were analyzed in detail, providing insights into visual attention and focus patterns. This methodological approach offers a unique perspective in our study and has contributed to the acquisition of more comprehensive results. To the best of our knowledge, this is the first study to compare 3 commonly used trimline alternatives. The influence of gender on smile esthetics was also considered, and its impact was examined. Eye-tracking technology uses digital oculo-metric data to assess visual attention by measuring fixation duration.<sup>17</sup> Thai et al<sup>14</sup> performed a comparison of attachments on anterior and posterior teeth using porcelain bracket alternatives and eye-tracking technology for analysis. In contrast, this study did not incorporate any attachments into the design, in line with the findings.

The literature suggests that age influences esthetic perception, which is why participants—comprising orthodontists, dental students, and nonspecialties—were selected to have similar ages.<sup>18</sup> Försch et al<sup>13</sup> conducted a study with 140 participants who were shown face and close-up images of various orthodontic appliances, including aligner appliances, aligners with attachments, lingual appliances, ceramic brackets, and the absence of any appliance. Eye movements and gaze direction were measured using an eye-tracking system, with the time to first fixation and total fixation time recorded for different anatomic regions and appliance areas. Participants also responded to questions using a visual analog scale to assess their perceptions and experiences. This study focused on the aligner groups and used close-up

smile photographs. In Försch et al,<sup>13</sup> all appliances, except for the lingual appliance, showed prolonged fixation times in the oral region. In the close-up smile photographs, ceramic brackets had the longest fixation time, followed by the aligner appliance with attachments. Analysis of the data revealed significant differences in the number of fixations, visits, and viewing times across the 3 trimlines for both genders. Significant differences were observed in the number of fixations, number of visits, and time until notice for the maxillary gingival line across the 3 trimlines in both genders.

Significant differences were observed in the mandibular gingival region regarding the number of fixations, number of visits, viewing time, and time until notice across the 3 trimlines for both genders. Similarly, significant differences were observed in the incisal edge region with respect to the number of fixations, number of visits, and viewing time across the 3 trimlines for both genders. The literature suggests that gender influences tooth shape, size, and alignment.<sup>19</sup> However, the results of this study, which focused on the trimline, were comparable among participants of both genders. This finding suggests that gender may not significantly influence trimline perception in patients with well-aligned teeth.

A study conducted in India revealed significant disparities in the awareness and perceptions of clear aligners among dental, medical, and paramedical students.<sup>20</sup> These findings suggested that medical and paramedical students demonstrated lower awareness and more negative perceptions than dental students. Unlike this study, which focused on assessing esthetic perception, the previous survey evaluated awareness. Our study, which aimed to assess esthetic perception, revealed no significant differences between the groups. This suggests that although awareness levels may differ across specialty groups, their perceptions regarding esthetics appear to align.

A study aimed at evaluating the public's esthetic perception of various dentogingival characteristics in relation to smile dynamics found that only 1 of 6 volunteer models met the esthetic criteria for dentogingival features, which included white, well-aligned teeth and an appropriate gingival contour.<sup>21</sup> The study revealed that smile and facial dynamics significantly influenced the perception of dentogingival changes, with diastema being identified as a factor that negatively impacted the assessment of both the mouth and face. It was also noted that variations in the lower third of the face, such as the cervical height of the maxillary central incisors (1 mm), the presence of a gummy smile (3-4 mm exposure), and a diastema between the central incisors (2 mm), contributed to perceptual differences. However, no significant difference was observed regarding

changes in the zenith point or misalignment. The trimlines of clear aligner treatments also contribute to distinct appearances in these areas. In this study, results showed that, for female subjects, the maxillary gingival line was lower for the extended trimline, whereas the straight edge was observed first. In contrast, the scalloped edge of the mandibular gingival line was noticed earlier. For male subjects, the upper scalloped edge was observed first, whereas the straight edge of the mandibular was noted first. These findings suggest that accounting for gender and individual differences, a longer edge with a higher termination may be less noticeable at the gingiva.

Putrino et al<sup>22</sup> allocated 100 participants (50 females and 50 males; age range, 15-70 years) into 2 groups: orthodontic and nonorthodontic. The smart eye-tracking technology application, implemented on smartphones, was used to evaluate participants' knowledge and perceptions of clear aligners. During the calibration phase, participants assessed images of smiles with various aligner types: no aligners, aligners with or without attachments, and aligners with straight or scalloped gingival margins, which served as the control group. The presence of attachments led to lower esthetic scores, with the lips redirecting focus away from the attachments, thereby enhancing the overall esthetic evaluation. Clear aligners without attachments received higher ratings overall. A statistically significant difference was observed in the duration of gaze directed at the longest-viewed photographs, particularly between the retractor-assisted straight trimline and the retractor-free scallop, as well as between the retractor-assisted and retractor-free scallop.

This study excluded evaluations conducted with a retractor, as such assessments were considered potentially misleading in simulating real-life conditions. The analysis revealed differences in eye-tracking values across trimlines between male and female subjects for all surfaces assessed. Furthermore, a discrepancy in viewing time at the incisal edges was observed between the genders. This could be attributed to variations in saliva accumulation within the aligner, which is influenced by trimline height, as observed in clinical practice. A possible explanation is that the increased thickness of the aligner at the incisal edges may attract greater visual attention.

The study by Putrino et al<sup>22</sup> indicated that the heatmap for the straight trimline condition displayed a concentration of gaze at the mandibular gingival margin, particularly in the mandibular right canine and incisor areas. In contrast, the scalloped trimline condition emphasized the gingival region of the maxillary incisors. Similarly, Försch et al<sup>13</sup> focused on the incisal edge of clear aligners, including those with attachments, within

the visual map. The heatmap analysis in this study shows patterns similar to those in prior research, especially regarding the incisal edges, which were also a key focus of this investigation.

Putrino et al<sup>22</sup> found that both attachments and trimlines were present simultaneously in the subjects, concluding that greater attention was directed toward the attachments. However, precise cuts were noted in some patients, which may have caused participants to focus on multiple areas. Thai et al<sup>14</sup> conducted a study that highlighted the areas of visual attention, with heatmaps showing red regions in the anterior and posterior attachment zones. In contrast, this study did not employ attachment designs or precise cuts; the focus was solely on the trimline.

Esthetic pretreatment smiles were found to negatively affect facial attractiveness, whereas orthodontic treatment led to a marked improvement.<sup>23</sup> The effects were particularly significant in subjects with more esthetically appealing facial features.<sup>23</sup> The study focused on close-up smile images based on the premise that facial esthetics and facial harmony are interrelated and can influence one another.

Individual eye characteristics, such as shape, size, and the use of eyeglasses or contact lenses, can affect the accuracy of eye-tracking measurements. Eye conditions such as nystagmus or strabismus may cause irregular eye movements. Environmental factors, including lighting and glare, also play a role in data quality. In addition, participant cooperation, fatigue, calibration variability, and the limited field of view of eye-tracking systems may contribute to inaccuracies.<sup>15,24</sup> In a recent study, participants were advised to turn off phone notifications, and the software reminded them to remove glasses. However, as the survey was conducted online, the environment in which participants took the survey and any potential distractions could not be controlled. Despite this, the software only included participants with moderate to high compliance, effectively excluding instances in which eye tracking was disrupted for various reasons. This approach was implemented to minimize the influence of such factors.

A recent study suggests that gender and hormone status may influence same-gender face recognition.<sup>25</sup> Although our study took participant gender into account, the current version of the software did not support gender-specific analysis.

The literature includes a limited number of studies using eye-tracking technology, and employing diverse methodologies could further contribute to advancing this field. One limitation of this study is the lack of observed differences among the groups in the survey data. In the eye-tracking analysis, the decision to

evaluate the groups collectively was made to reduce data complexity. Future studies should consider evaluating fewer participants across various specialty groups to expand and enhance the existing literature.

## CONCLUSIONS

1. The conventional survey methods revealed no significant differences among the 3 specialty groups evaluated.
2. Gender differences were found to influence the perception of close-up smiles.
3. Scalloped and straight trimlines were the most frequently observed, with the extended trimline design appearing to be more favorable in social contexts.

## AUTHOR CREDIT STATEMENT

Merve Kurnaz contributed to conceptualization, methodology, software, visualization, investigation, and original draft preparation; Nuray Akbıyık contributed to data curation, original draft preparation, methodology, and conceptualization; Semir Öztürk contributed to data curation, visualization, investigation, and conceptualization; and Sibel Biren contributed to supervision, validation, and manuscript review and editing.

## REFERENCES

1. Rossini G, Parrini S, Castroflorio T, Deregibus A, Debernardi CL. Efficacy of clear aligners in controlling orthodontic tooth movement: a systematic review. *Angle Orthod* 2015;85:881-9.
2. Kesling HD. Coordinating the predetermined pattern and tooth positioner with conventional treatment. *Am J Orthod Oral Surg* 1946;32:285-93.
3. Zheng M, Liu R, Ni Z, Yu Z. Efficiency, effectiveness and treatment stability of clear aligners: a systematic review and meta-analysis. *Orthod Craniofac Res* 2017;20:127-33.
4. Fujiyama K, Honjo T, Suzuki M, Matsuoka S, Deguchi T. Analysis of pain level in cases treated with Invisalign aligner: comparison with fixed edgewise appliance therapy. *Prog Orthod* 2014;15:64.
5. Miller KB, McGorray SP, Womack R, Quintero JC, Perelmuter M, Gibson J, et al. A comparison of treatment impacts between Invisalign aligner and fixed appliance therapy during the first week of treatment. *Am J Orthod Dentofacial Orthop* 2007;131:302.e1-9.
6. Boyd RL. Esthetic orthodontic treatment using the Invisalign appliance for moderate to complex malocclusions. *J Dent Educ* 2008;72:948-67.
7. Cowley DP, Mah J, O'Toole B. The effect of gingival-margin design on the retention of thermoformed aligners. *J Clin Orthod* 2012;46:697-702.
8. Lombardo L, Palone M, Longo M, Arveda N, Nacucchi M, De Pascalis F, et al. MicroCT X-ray comparison of aligner gap and thickness of six brands of aligners: an in-vitro study. *Prog Orthod* 2020;21:12.
9. Elshazly TM, Salvatori D, Elattar H, Bourauel C, Keilig L. Effect of trimming line design and edge extension of orthodontic aligners on force transmission: a 3D finite element study. *J Mech Behav Biomed Mater* 2023;140:105741.
10. Favero R, Libralato L, Balestro F, Volpato A, Favero L. Edge level of aligners and periodontal health: a clinical perspective study in young patients. *Dental Press J Orthod* 2023;28:e2321124.
11. Clune J. The immediate effects of aligners and aesthetic fixed appliances on smiling and perceptions in young adults. [thesis]. Cork: University College Cork; 2018.
12. Alansari RA. Youth perception of different orthodontic appliances. *Patient Prefer Adherence* 2020;14:1011-9.
13. Förtsch M, Krull L, Hechtner M, Rahimi R, Wriedt S, Wehrbein H, et al. Perception of esthetic orthodontic appliances: an eye tracking and cross-sectional study. *Angle Orthod* 2020;90:109-17.
14. Thai JK, Araujo E, McCray J, Schneider PP, Kim KB. Esthetic perception of clear aligner therapy attachments using eye-tracking technology. *Am J Orthod Dentofacial Orthop* 2020;158:400-9.
15. Cho VY, Loh XH, Abbott L, Mohd-Isa NA, Anthonappa RP. Reporting eye-tracking studies in dentistry (reside) checklist. *J Dent* 2023;129:104359.
16. Al Tuwirqi AA. Eye-tracking technology in dentistry: a review of literature. *Cureus* 2024;16:e55105.
17. Fuentes S, Gonzalez Viejo C, Torrico DD, Dunshea FR. Digital integration and automated assessment of eye-tracking and emotional response data using the BioSensory app to maximize packaging label analysis. *Sensors (Basel)* 2021;21:7641.
18. Sriphadungporn C, Chamnanmadiadha N. Perception of smile esthetics by laypeople of different ages. *Prog Orthod* 2017;18:8.
19. Antoszewski B, Zadzzińska E, Foczpański J. The metric features of teeth in female-to-male transsexuals. *Arch Sex Behav* 2009;38:351-8.
20. Sadhunavar T, Nilgar A, Santhosh VN, Jalihal S, Shankkari S. Awareness and perception of dental, medical, and paramedical students toward the use of clear aligners in orthodontic treatment in Belagavi, India. *Cureus* 2024;16:e64737.
21. Malheiros AS, Barboza JR, Pinheiro Neto SM, Dibai DB, Maia Filho EM, Pinzan-Vercelino CM, et al. Laypersons' esthetic perception of different dentogingival characteristics based on smile dynamics: cross-sectional study. *Int J Dent* 2024;2024:5561640.
22. Putrino A, Marinelli E, Raso M, Calace V, Zaami S. Clear aligners and smart eye tracking technology as a new communication strategy between ethical and legal issues. *Life (Basel)* 2023;13:297.
23. Farshidnia S, Morid M, Damavandi M, Tahamtan S. Effect of smile on facial attractiveness before and after orthodontic treatment in females with more attractive and less attractive facial background. *Am J Orthod Dentofacial Orthop* 2023;164:657-64.
24. Birawo B, Kasproski P. Review and evaluation of eye movement event detection algorithms. *Sensors (Basel)* 2022;22:8810.
25. Hausinger T, Probst B, Hawelka S, Pletzer B. Own-gender bias in facial feature recognition yields sex differences in holistic face processing. *Biol Sex Differ* 2025;16:14.