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RESEARCH AND EDUCATION

Perception of occlusal plane that is nonparallel to interpupillary and commissural lines but with the maxillary dental midline ideally positioned

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ABSTRACT

Statement of problem. How disparities in parallelism between the occlusal plane and the interpupillary (IP) or commissural facial front lines are perceived is unclear.

Purpose. The purpose of this observational study was to examine the perceptions of laypersons, dental students, and dentists regarding disparities of the anterior occlusal plane (AOP) and posterior occlusal plane (POP) with respect to the IP and commissural line (CL) with the maxillary dental midline ideally positioned.

Material and methods. A model of a symmetric female face was digitally created with the IP and CL parallel and the facial midline coincident with the maxillary dental midline. Two groups of images were created, one with the POP modified in 1-degree increments, in which both the maxillary dental midline and the position of the maxillary central incisors were not manipulated, and the other with the POP modified in the same increments but with the position of both maxillary central incisors lengthened to follow the inclination of the occlusal plane. Participants (N=312) were asked to rate the images on a 1-to-6 scale. The Kruskal-Wallis medians test and ordinal logistic regression were used to analyze the ratings.

Results. Group median ratings for different occupations gradually decreased with increased inclination of the occlusal plane. Significant differences were found for inclinations from 2 to 5 degrees. Significant odd ratios were found for age and sex.

Conclusions. Dental professionals detected smaller POP disparities. The dentist and dental student groups gave lower ratings in proportion to the amount of POP inclination. Laypersons gave lower ratings only after 3 degrees of POP inclination but still graded all the images as esthetically pleasant. Older people and men tended to give higher ratings to the same image. (J Prosthet Dent 2019;122:482-90)

In 1936, Pilkington[1] defined dental esthetics as the science of copying or harmonizing a dental rehabilitation with nature. Esthetics remain an impression of the mind motivated by its own perception; therefore, beauty remains a subjective concept.[2] This subjective connotation is one of the factors that differentiate the ability of individuals to become aware of and interpret dental parameters in a different manner.[3]

The integration of dental prostheses into the patient's face and smile is a determinative factor for esthetically pleasing restorative success. Previous studies have reported that dental professionals and laypersons were able to detect discrepancies in smile characteristics at differing

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Clinical Implications

By understanding the parameters at which a layperson would notice occlusal plane disparities and its relation to the parameters of dental professionals, clinicians gain insight into the optimal restorative procedure.

levels and that, for many variables, laypersons were less discriminating than practitioners.[4-16]

For patients whose occlusal plane requires modification through prosthodontic treatment, a facially driven diagnostic waxing and an esthetic template are recommended.[17-19] Those procedures allow predicted treatment outcomes to be directly visualized in the mouth, where esthetically unpleasant thresholds can be used by dental professionals to aid in treatment planning.

Previous studies have analyzed esthetic subjective perception at different inclinations of the occlusal plane. Most of those protocols included only the display of the lower third and the alteration of the maxillary occlusal plane and maxillary midline together at different inclines. The results of those studies showed that deviations in occlusal plane inclinations were not noticeable by laypersons unless they exceeded 2,[14] 3,[5] or 4 degrees.[6,7,16] However, studies that compared and evaluated individual perceptions regarding an altered anterior and/or posterior occlusal plane (POP) without altering the position and inclination of the maxillary dental midline are lacking.

The purpose of the present study was to measure differences in the perceptions of laypersons, dental students, and dentists regarding disparities between the anterior and POPs and the facial references. The null hypothesis was that no statistically significant differences in the perception of disparities between the anterior and POPs relative to the interpupillary and commissural line (CL) in a female face viewed from the front would be found between laypersons, dental students, and dentists.

MATERIAL AND METHODS

The protocol was approved by the Institutional Review Board (IRB) of the College of Dentistry at Texas A&M University (IRB 2018-0696). The survey was anonymous. The surveyed participants were all over 18 years of age and were recruited at the Texas A&M Health Science Center. Non-English speakers, pregnant women, individuals with physical disabilities, individuals with cognitive disabilities, prisoners, and individuals with psychiatric disorders or emotional/social impairments, and individuals with depression were excluded.

A symmetrical female facial model was created digitally (Photoshop CS5; Adobe Systems) with the interpupillary line (IP) parallel to the CL (Fig. 1A). The facial midline was coincident with the maxillary dental midline. A medium lip line and a convex smile line were employed in the simulation (Fig. 1B). The anterior occlusal plane (AOP) was defined as the plane formed by the incisal edges of both maxillary central incisors, and the POP was defined as the plane formed by the buccal cusps of the posterior teeth. The axis of rotation used to incline the occlusal plane was located at the intersection of the maxillary dental midline and at the incisal edges of the central incisors.

Two groups of images were created. In 1 group (Post group), the AOP remained unchanged, but the POP was modified in incremental inclinations of 1 degree (0, 1, 2, 3, 4, and 5 degrees) down to the patient's left (Fig. 2). The maxillary dental midline and the position of both maxillary central incisors were not manipulated. In the second group (Ant+Post group), the POP was modified by the same increments as in the Post group; however, the position of both maxillary central incisors was lengthened to follow the inclination of the occlusal plane, without changing the inclination of the maxillary dental midline (Fig. 3). In all images, the occlusal plane was inclined by manipulating the length of the clinical crowns of the maxillary teeth, thereby maintaining the medium lip line without showing the gingival margins of the teeth.

Three populations, each containing 104 individuals, were surveyed: laypersons, dental students, and dentists. A total of 312 individuals were asked to evaluate each image according to their own esthetic criteria by using a visual scale from 1 to 6, where 1 was the least esthetically appealing and 6 was the most esthetically appealing. The sequence of presentation of the images was randomized each time for each participant.

Nonparametric statistical tests were used to analyze the data, as an ordinal categorical scale was used rather than a continuous variable rating scale (1 to 6).[20] Confidence intervals (CIs; 95%) for the medians were calculated as 1.78 times the interquartile range.[21] The responses to each individual image were analyzed by using the Kruskal-Wallis medians test, with picture rating as the dependent variable and participant occupation group (dental student, dentist, and layperson) as the independent/grouping variable.[22]

Furthermore, to know the presence and degree of the effect of independent variables such as age, sex, amount of inclination of the POP for each of the AOP inclination groups, and the occupation group on the rating of the face picture, an ordinal logistic regression was used.[20,23] Ratings were the dependent ordinal variable again, and sex (binomial scale), age (interval scale), the degree of tilt of the POP (interval scale), AOP group (binomial), and occupation group (multinomial scale) were the explanatory variables. Interaction terms between the occupation

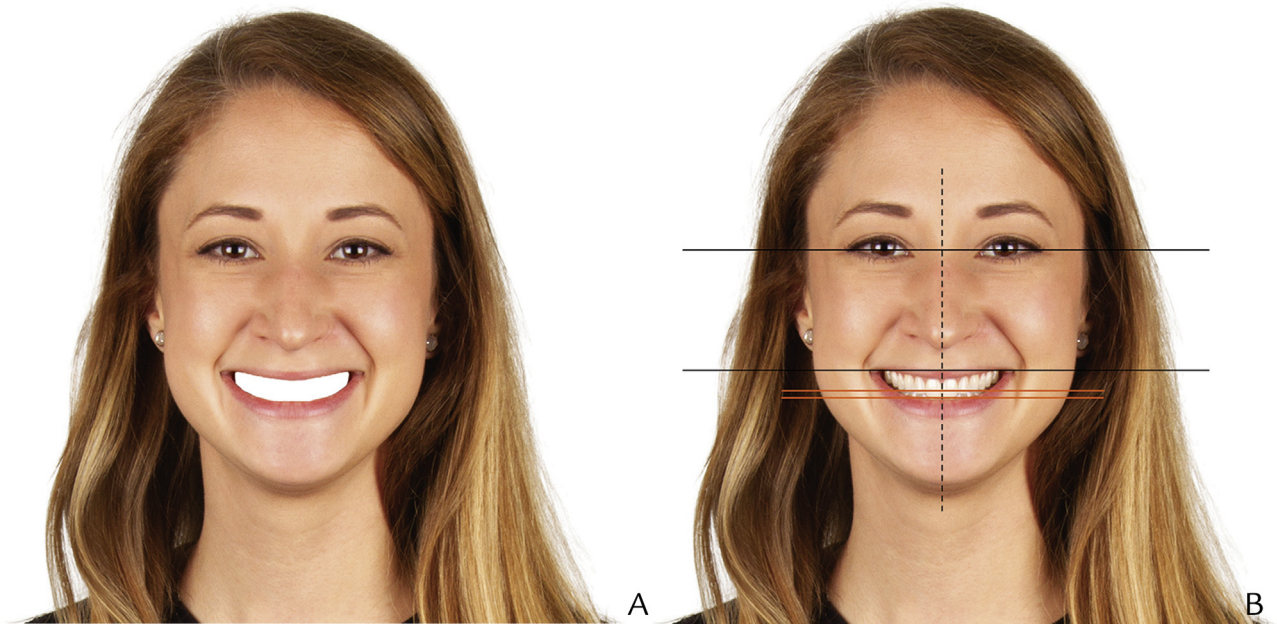

Figure 1. A, Digitally edited female facial symmetric model created (Photoshop CS5; Adobe Systems) with interpupillary line (IP) and commissural line (CL) parallel. B, Facial midline coincident with maxillary dental midline, medium lip line, and convex smile line determined. The anterior and posterior occlusal planes were paralell.

group and POP tilt and between age and sex were also included. A proportional odds assumption was made because it allowed the estimation of the parameters of the logistic regression and the odds ratios (OR) for the effect of each variable. To determine the effect size of the regression, an R^2 coefficient of the linear predictor on the logit transform of the probabilities was determined.[24] To further validate the effect of the variables, a multivariate linear regression was performed on raw ratings by using the same independent variables as the ordinal logistic regression. Ordinal regression analysis was performed in the R statistical environment[25] by using the VGAM software package.[26]

RESULTS

A total of 312 people were surveyed (Table 1). The results showed that the ratings became lower with increased POP inclination. Also, group ratings gradually diverged, with the layperson group giving consistently higher ratings than the other 2 groups (Figs. 4, 5). In both Ant+Post and Post groups, the inclination of 0 and 1 degrees revealed no differences in ratings among the dentist, dental student, and layperson groups. As the inclination increased, group ratings became significantly different. The median rating in the Post and Ant+Post groups for 5-degree POP inclination was 4, but the median rating for the same inclination by dental professionals was 2.

Overall, dentists and dental students gave a median response rating of 4, whereas laypersons gave a median response rating of 5 to the set of all images. Moreover, for both Post and Ant+Post groups, the occupation group differences were statistically significant for all POP inclinations greater than 1 degree (data not shown).

ORs and their 95% CIs based on the ordinal logistic regression coefficients are presented in Table 2. ORs for the occupation group (laypersons), POP inclination, interaction between occupation and POP inclination, age, sex, and age×sex interaction were significant at α=.05. The insignificant OR for the occupation group dentist (OR=0.88, 95% CI: 0.74-1.04) meant that this group was not statistically different from the dental student group. However, both groups were significantly different from the layperson group, with the layperson group projected to give lower ratings than either dentist or dental student group (OR=0.52<1.0). That is, the odds of giving higher/lower rating for dentists and dental students versus laypersons were different by a factor of 2 (=1/0.52), with laypersons giving lower ratings. However, the significant OR for the interaction between layperson occupation and POP inclination (OR=1.7>1.0) indicated that laypeople tended to give relatively higher ratings as the POP tilt increased than the other 2 occupation groups.

OR for age indicated that older people tended to give higher ratings to the same picture (OR=1.4>1.0). That is, the odds of lower versus higher ratings increased for each subsequent age group by a factor of 1.4. The greater the age group, the higher the ratings. Similarly, men tended to give slightly higher ratings than women (OR = 1.4>1.0). However, significant sex×age interactions

Figure 2. Post group images, AOP remained unchanged, but POP modified in 1-degree increasing incremental inclinations down to patient's left. A, 0 degree. B, 1 degree. C, 2 degrees. D, 3 degrees. E, 4 degrees. F, 5 degrees. AOP, anterior occlusal plane; POP, posterior occlusal plane.

Figure 3. Ant+Post group images, POP modified in same increments as Post group; however, position of both maxillary central incisors was lengthened to follow inclination of occlusal plane without changing inclination of maxillary dental midline. A, 0 degree. B, 1 degree. C, 2 degrees. D, 3 degrees. E, 4 degrees. F, 5 degrees. POP, posterior occlusal plane.

Table 1. Characteristics of different populations surveyed

Group	Number of Individuals per Group	Sex	Age Range: Number of Participants
Dental students	104	53 women (50.96%); 51 men (49.04%)	18-25 y: 62 participants 26-35 y: 39 participants 36-45 y: 2 participants 46-55 y: 0 participants 56-65 y: 1 participant 66-80 y: 0 participants +81 y: 0 participants
Dentists	104	39 women (37.50%); 65 men (62.50%)	18-25 y: 3 participants 26-35 y: 31 participants 36-45 y: 22 participants 46-55 y: 21 participants 56-65 y: 15 participants 66-80 y: 11 participants +81 y: 1 participant
Laypersons	104	65 women (62.50%); 39 men (37.50%)	18-25 y: 7 participants 26-35 y: 8 participants 36-45 y: 15 participants 46-55 y: 19 participants 56-65 y: 25 participants 66-80 y: 27 participants +81 y: 3 participants

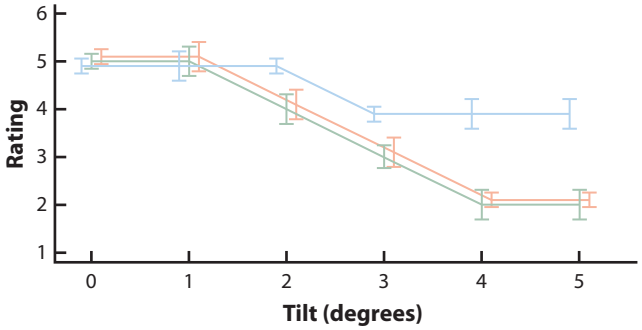

Figure 4. Occupation group medians and 95% CI as function of POP tilt for unchanged AOP. Ratings by dentists are presented in green, dental students in red, and laypersons in blue. Lines for dental student and layperson groups staggered by plus or minus 0.1 to prevent line overlap. AOP, anterior occlusal plane; CI, confidence interval; POP, posterior occlusal plane.

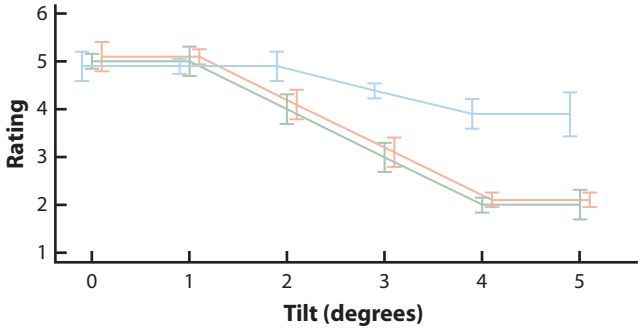

Figure 5. Occupation group medians and 95% CI as function of POP tilt for adjusted AOP. Ratings by dentists are presented in green, dental students in red, and laypersons in blue. Lines for dental student and layperson groups staggered by plus or minus 0.1 to prevent line overlap. AOP, anterior occlusal plane; CI, confidence interval; POP, posterior occlusal plane.

indicated that the degree of the sex effect depended on age, with younger women giving slightly higher ratings than older men (OR=0.86<1.0).

Importantly, significant OR for the POP inclinations meant that with greater POP inclination, the ratings were lower (OR=0.36<1.0). The insignificant OR for the Ant+Post group indicated that changing the maxillary central incisor length to match the inclination of the rest of the occlusal plane had no separate effect on the ratings. Based on the OR value, POP tilt had the strongest effect on the rating (1/OR=2.293), followed by the occupation group-layperson variable, layperson-POP tilt interaction, age and sex variables, and, finally, age×sex interaction, which had the least but still significant effect. The R^2 for the linear regression on the link function of the ratings was 0.435.

Performing a linear regression on the raw ratings yielded essentially the same results (Table 3). In the occupation group, POP inclination (POP tilt), the interaction between occupation group and POP inclination, age, sex, and the interaction between them were, again, significant, with coefficients (not shown) indicating the same direction and relative magnitude of the effect as the ORs for the corresponding variables from the ordinal regression analysis. R^2 of the linear regression was 0.468 (adjusted R^2=0.465).

DISCUSSION

The objective of this study was to analyze the perception on the occlusal plane inclinations related with the facial parameters. For that reason, in the present study, the variables that previous authors showed as unpleasant, such as inclination of the maxillary dental midline and gingival display, remained unaltered.[5-7,14,16] A full facial image was presented for rating so that the participant had all the facial references to analyze the smile inside the frame of the face. In addition, a medium lip line and convex smile line were selected based on previous studies

Table 2. Odds ratios (ORs) and their 95% CIs based on regression coefficients from proportional odds ordinal logistic regression with repeated measurements of image rating versus occupation group, age, sex, POP tilt, AOP group, sex×age interaction, and POP tilt×AOP group interaction

Variable	OR*	Lower 2.5% Bound	Upper 2.5% Bound
Group dentist	0.7756014	0.591417	1.0171463
Group layperson	**0.5243474**	0.3923839	0.7006919
POP tilt	**0.3687775**	0.3450285	0.3941612
AOP group	0.9434149	0.840118	1.0594125
Age	**1.3850034**	1.303316	1.4718107
Sex-Man	**1.400688**	1.1073589	1.7717174
Group dentist: POP tilt	1.0560732	0.970512	1.1491777
Group layperson: POP tilt	**1.7121671**	1.5701384	1.8670432
Age: Sex-Man	**0.8634895**	0.8070967	0.9238224

AOP, anterior occlusal plane; CI, confidence interval; POP, posterior occlusal plane. Dental student group served as reference group for dentist and layperson groups. *95% CI that include 1.0 not statistically different from no effect. ORs below 1.0 indicate that increase in variable contributed to decrease in rating of pictures; conversely, OR greater than 1.0 meant that increase in variable (or change from "women" to "men" and change to "layperson"—in case of the nominal variables) led to increase in ratings, with all other variables held constant. Statistically significant ORs shown in bold. *Because ORs presented here reflect high/low odds for ease of interpretation as opposed to low/high odds used in computations, ORs presented here inverted relative to software outputs.

Table 3. ANOVA of linear regression of raw ratings on tilt, occupation group, anterior occlusal plane group, age, sex, and individual

Variable	Df	SS	MS	F Value	P
Group	2	638.9	319.44	244.922	**<.001**
POP tilt	1	3058.8	3058.85	2345.2587	**<.001**
AOP group	1	1.9	1.93	1.4796	.224
Age	6	192	32	24.5386	**<.001**
Sex	1	5.3	5.33	4.0843	**.043**
Person	1	1.9	1.92	1.4732	.225
Group×POP tilt	2	284.6	142.29	109.0946	**<.001**
Age×sex	6	80.9	13.49	10.3407	**<.001**
Residuals	3723	4855.8	1.3		

AOP, anterior occlusal plane; POP, posterior occlusal plane.
Significant diferences (P>.05) are presented in bold.

that concluded that those parameters were the most frequent in the population.[27] The null hypothesis of the study was rejected because statistically significant differences were found between dentists, dental students, and laypersons on the rating of different disparities between the POPs and the interpupillary and CL in a facial frontal view.

Overall, dentists and dental students rated the images lower than the laypersons, as indicated by the Kruskal-Wallis tests. Based on the ordinal regression, no significant differences were found between AOP groups that differed in the adjustment of the position and inclination of the maxillary central incisors. Two results can be differentiated: the generally lower rating of occlusal plane discrepancies by dental professionals than that by laypersons and the lesser esthetically pleasant ratings by dental professionals (dentists and dental students) than that by laypersons with increased POP inclinations.

Overall, all participants decreased their ratings with increased inclination of the POP as indicated by the significant OR for that variable. However, from 2 to 5 degrees of inclination, significant differences were found between dental professionals and laypersons as indicated by the presence of a strong interaction between the occupation group and POP inclination. The result from the ordinal regression that laypersons would in general give lower ratings than the dental professionals contradicts the findings from the overall Kruskal-Wallis test and is probably because of the presence of a strong occupation group-POP inclination interaction effect and thus cannot be considered separately. Most likely, the counterintuitive value for the OR for laypersons resulted from the presence of numerous high ratings in all groups at the edge of the domain (POP tilt=0) and slower fall off in the ratings for the laypersons with increased tilt. Thus, dental professionals gave lower ratings for the occlusal cant disparities than laypersons. The dentists and dental students consistently gave lower scores as the inclination increased. In general, similar to the dental professionals, laypersons gave lower ratings to a change of 3 or more degrees of occlusal cant but still graded all the images as esthetically pleasant (median rating 4).

Both the ordinal and plain linear regressions displayed a rather poor fit as indicated by their R^2 values, 0.435 and 0.468, respectively. The poor fit of the linear regression probably stems from the fact that it was fit to discreet data with a limited range (1 through 6) that were heteroscedastic and not symmetrically distributed and, thus, violated common assumptions of the linear regression. The low R^2 of the ordinal regression is not directly related to the poor fit of the observed data but rather to the fit of the logit of the probabilities for different ratings. Thus, the low R^2 probably reflects a great spread of the responses for the different people with an identical set of explanatory variables in the present study. The fact that both models gave identical results as to the significance, direction, and relative magnitude of the effects of different variables gives validity to the findings.

The finding that dental professionals are able to perceive smaller occlusal plane disparities is consistent with previous studies.[7,16] This could be explained by the fact that dental professionals are more accustomed to seeing and addressing small differences in facial appearance. A trained participant such as a dental professional or a layperson with specific training on the evaluated esthetic parameters would be able to detect lesser inclinations of the occlusal plane.

In 1999, Kokich et al[7] evaluated the occlusal cant perception of orthodontists, general dentists, and laypersons. The AOP was canted in 1-mm increments by rotating around a central point at the incisal embrasure between the central incisor crowns in a smile image, the maxillary dental midline followed the cant of the AOP. Both orthodontists and general dentists detected a 1-mm

anterior plane asymmetry, but a 3-mm (equivalent to 4 degrees) cant was required for the lay group to rate it as noticeable and less attractive. Kerr et al[16] evaluated the perception of the occlusal cant on a lay population. The authors inclined the dentition in one-quarter-degree increments in a clockwise direction from 0 to 6 degrees in a lower facial third photograph; the maxillary dental midline also followed the inclination of the occlusal plane. The maximum tolerated by those surveyed was 4 degrees.

Differences in the research protocol, such as facial lower third versus complete face image, parallelism between the facial and maxillary dental midlines, and anterior versus anterior and POP inclinations, make comparison with some of the previous studies difficult.

Based on the results of the present study, the layperson group rated an occlusal plane canted up to 5 degrees as esthetically pleasant. This outcome could be related to the parallelism between the maxillary dental midline and the facial midline and even the gingival display in all the images surveyed. Kokich et al[7] demonstrated that the inclination of the maxillary dental midline related to the facial midline is a more critical factor and more noticeable in the perception of an esthetically pleasant smile than the paralleled and laterally displaced maxillary dental midline.

In the present study, sex was a factor that influenced the perception of the occlusal plane inclination, which is consistent with previous studies.[27,28] Age also showed an effect on the occlusal plane perception, where the higher the age, the higher the rating, demonstrating that with age, people were less critical of esthetic parameters, which is also consistent with previous studies.[5]

The differing levels of detectability demonstrate that minor variations in specific dental esthetic discrepancies may not be an important concern to most patients. Therefore, it is the responsibility of clinicians to inform the patient of noticeable deviations and then allow the patient to make his or her own determination as to the overall esthetic significance of each discrepancy. Based on the results of the present study, laypersons gave lower ratings to a change of 3 or more degrees of occlusal cant (only evaluated up to 5 degrees) but still graded all the images as esthetically pleasant. By understanding the parameters at which a layperson would notice occlusal plane disparities and their relation to the parameters of dental professionals, clinicians gain insight into the optimal restorative procedure.

The present study used images from a single full-face smile in which a specific feature was modified by using a photographic editing software program. Those survey studies are limited in the number of parameters they can assess, and none provided sufficient information for a comprehensive definition of an appealing smile.[29] Further studies where bigger thresholds or discrepancies are evaluated are recommended to further analyze the perception differences between dentists, dental students, and laypersons.

CONCLUSIONS

Within the limitations of the present study, the following conclusions were drawn:

1. Dental professionals gave lower ratings to the smaller occlusal cant disparities than laypersons. However, all groups decreased their ratings with increased inclination of the POP.
2. The inclination of 0 and 1 degrees revealed no differences among dentists, dental students, and laypersons. However, from 2 to 5 degrees of inclination, significant differences were found between dental professionals and laypersons. While the dentist and the dental student groups gave gradually lower ratings as the inclination increased, laypersons gave lower ratings only up to a change of 3 degrees or more in occlusal cant; this group still graded all the images as esthetically pleasant.
3. The AOP had no effect on the esthetically pleasant rating of the dentists, dental students, and laypersons.
4. Sex and age were factors that influenced the rating of the occlusal plane inclination; older people tended to give higher ratings to the same image, and men gave slightly higher ratings than women. The effect was significant but not as strong as the effect of the POP tilt.

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Noteworthy Abstracts of the Current Literature

A prospective clinical study of alumina-toughened zirconia abutments for implant-supported fixed restorations with a mean follow-up period of 6.9 years

Yoon HI, Yeo IL, Kim DJ, Kim HY, Han JS

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Purpose. The goal of this study was to compute the estimated cumulative survival and success rates of alumina-toughened zirconia (ATZ) abutments used for external connection-type implant-supported fixed dental prostheses (FDPs) after a mean follow-up of 6.9 years (82.3 months).

Material and methods. From May 1998 to July 2016, patients who provided informed consent and received implant-supported restorations with ATZ abutments were recruited. Clinical performance of zirconia abutments was evaluated using survival analysis. Failure was defined as the removal of the restoration due to zirconia abutment fracture, and complications included both failure and abutment screw problems. Survival and success were the counterparts of failure and complications, respectively. The effects of restoration-related factors (restored area, type of prosthesis, and implant system) on the survival and success of the abutments were estimated.

Results. A total of 231 patients were included in this study. One hundred twenty-six implant-supported single-unit and 204 multiple-unit FDPs were evaluated. All the placed implants had the external hex connection. The estimated cumulative 5-year, 7-year, and 10-year survival rates (95% confidence interval [CI]) of zirconia abutment-supported FDPs were 97.3% (95.5% to 99.1%), 96.8% (94.8% to 98.8%), and 94.1% (90.4% to 97.8%), respectively. The estimated cumulative 5-year, 7-year, and 10-year success rates (95% CI) were 94.1% (91.4% to 96.8%), 90.8% (87.3% to 94.3%), and 80.1% (73.6% to 86.6%), respectively. The type of prosthesis (P=.001) and implant system (P<.001) were the significant factors in the success of zirconia abutment-supported FDPs.

Conclusions. Prefabricated ATZ abutments have a high predictability of survival at 10 years when used in implant-supported FDPs that replace both anterior and posterior teeth. However, the success of zirconia abutments was significantly influenced by the type of prosthesis and implant system.