# Ability of General Dentists and Prosthodontists to Discern and Identify Incremental Increases in Occlusal Vertical Dimension in Dentate Subjects

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***Purpose:*** The aim of this study was to determine whether dentists are able to discern and identify increases in occlusal vertical dimension (OVD) in dentate subjects without apparent loss of OVD. ***Materials and Methods:*** A total of 10 dentate subjects had mandibular overlays fabricated at 2-, 3-, 4-, and 5-mm openings of the anterior guide pin (AGP) of a semiadjustable articulator. Standardized frontal and profile photographs with subjects wearing each of the overlays were made. Photographs were presented in random order to 40 judges comprising 20 prosthodontists and 20 general dentists who were informed about the purpose of the study. Judges first rated the degree of facial naturalness on a visual analog scale (VAS) and then took a discriminatory sensory analysis test (triangle test) where they were required to correctly identify the image with no increase in OVD from a set of three images. ***Results:*** Mean VAS ratings for facial naturalness were inversely correlated with incremental increases in OVD, irrespective of the judge's background. Though subjects were rated less natural with incremental increases in OVD, only a 5-mm increase from baseline was clinically significant ($P < .05$). For the triangle test, judges correctly identified the image with a 3-mm increase in OVD 57% of the time ($P < .582$), irrespective of the judge's profession, sex, race, and years in practice, which were clinically insignificant. ***Conclusion:*** Increasing OVD by a 5-mm opening of the AGP of the articulator significantly decreased the judge's evaluation of facial naturalness. The ratings were more pronounced in female subjects than in male subjects. However, an increase in OVD of 3 mm was visually indistinguishable by the judges. *Int J Prosthodont 2017;30:327–333. doi: 10.11607/ijp.5152*

Various methods are widely accepted by clinicians to record occlusal vertical dimension (OVD) (formerly termed *vertical dimension of occlusion* or VDO) in removable and fixed prosthodontics.[1] The clinical assessment and decision to increase a patient's OVD should rely on an eclectic approach that incorporates the patient's restorative needs, esthetics, occlusion, facial form, and ability of the jaw muscles to tolerate the increase.[2] Of these factors, facial esthetics assumes an important aspect, as patients perceive it as the true end point of dental treatment. In this regard, there is minimal scientific literature that has examined the effect of OVD on facial esthetics in dentate patients.[2,3] Most of the classic literature on OVD has been devoted to complete denture prosthodontics, where facial esthetics is often compromised by a myriad of other factors.[1]

In dentate patients, OVD can be examined in two perspectives with respect to facial esthetics. First, clinicians may be inclined to perform a complete-arch or complete-mouth dental rehabilitation based on their assessment of a patient's need for increase in OVD or diagnosis of loss in OVD, to compensate for facial esthetics. Both of these diagnoses are arguably subjective and result in unnecessary and expensive treatment. Second, clinicians are often concerned that increasing the OVD of a dentate patient who has no loss in OVD may negatively affect facial esthetics. This is based on the assumption that increase in OVD has a linear relationship with increase in lower facial height (LFH) and thus affects facial esthetics.

Presently, there are only two studies that have lent clarity on this topic.[2,3] In a study of 22 dentate subjects, Gross et al[3] made maxillary overlays of 2-, 4-, 6-, and 8-mm thicknesses and made photographs. Judges were then asked to rank the images in order of ascending LFH. Results showed that the judges were not able to arrange the images in any homogenous

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ascending order, suggesting no subjective change in LFH existed with increasing OVD. The authors concluded that attempts to alter face height by changing OVD by 2 to 6 mm for esthetic reasons might not be visually distinguishable. A recent study by Orenstein et al[2] fabricated mandibular overlays with thicknesses of 2, 3, 4, and 5 mm on a semiadjustable articulator. The frontal and profile digital images were presented to 60 judges comprised of 30 laypeople, 15 general dentists, and 15 prosthodontists for rating of facial esthetics on a visual analog scale (VAS). It was concluded that incremental increases in anterior guide pin opening of up to 5 mm did not correlate to similar increases in LFH. Additionally, a judge's background status (layperson, general dentist, or prosthodontist) or sex did not make a difference in that judge's evaluation of facial esthetics.[2]

In both of these studies, the observer (judge) was blinded to the purpose of the study to remove any confounders and derive an unbiased assessment of OVD for the images being rated. It is unknown whether the study outcomes would have been different if the judges knew what to look for when rating the images. Additionally, it would be helpful to know whether dentists have the ability to clearly discern and identify frontal and profile images with incremental increases in OVD. The purpose of this study was therefore to determine whether dentists are able to discern and correctly identify increase in OVD in dentate subjects. In this study, the dentists were not blinded to the purpose of the study and were educated about what to identify in each image.

## Materials and Methods

This study was approved by the University Institutional Review Board (#12-130-2), and a detailed explanation of the materials and methods for subject recruitment, judge recruitment, fabrication of mandibular overlays, and digital photography methods are described in a previous study by Orenstein et al.[2] A brief summary of subjects is presented here. A minimum of two subjects from each of the following racial backgrounds were selected for the study: white (45%), black (15%), Asian (20%), and South Asian (20%). All subjects fulfilled the following predetermined inclusion criteria: (1) complete maxillary and mandibular dentition in Class I relationship, (2) no history of orthognathic or plastic surgery, (3) no gross facial asymmetries, and (4) no history of any congenital conditions/trauma affecting facial form and appearance. Of the subjects, 35% were women and 65% were men. The average age of subjects was 26.6 years.

To assess changes in OVD and facial naturalness of the images, 40 judges comprising 20 general dentists and 20 prosthodontists were recruited. The judges selected for this study were not identical to those reported in the first study.[2] The racial characteristics of the judges were 87% White, 8% Asian, and 5% Asian-Indian. Of these, 40% were women and 60% were men. The average age of the judges was 41.25 years, and their average clinical experience was 13.6 years. Judges were required to provide an affirmative answer (yes/no) if they recognized any of the subjects in the study after the first round of judging. If the answer was yes, the judge was excluded from the study to eliminate any bias in evaluations.

For this study, frontal and profile digital photographs of 10 subjects were selected. The images were made at baseline (no overlay in the mouth), with subjects wearing mandibular overlays fabricated at 2-, 3-, 4-, and 5-mm openings of the anterior guide pin (AGP) of a semiadjustable articulator. The study comprised two parts to satisfy two different objectives. The first part was discernment of facial naturalness with incremental increases in OVD using the VAS method. The second part was ability to identify the image with no increase in OVD among a set of images using a triangle test, which is a discriminatory sensory analysis test in which assessors are required to identify the correct sample out of three samples, where two samples are identical and one is slightly different.[4–6]

For the first part of the study, a total of 5 frontal and 5 profile images for each subject (total of 100 images) were available for presentation to judges. The 100 images were compiled in a digital slide presentation program (PowerPoint 2010, Microsoft). Each slide contained the frontal image and profile image of the same subject at the same OVD, for a total of 50 slides. All judges were required to evaluate all images twice. Therefore, two slideshows were created with trial 1 comprising 50 slides in a randomized sequence and trial 2 using the same 50 slides in a different randomized sequence. The judges were first educated about the VAS method for rating and informed that although subjects were photographed with various thicknesses of overlays, no single pair of images had the same OVD. The judges were clearly informed and educated about the nature and purpose of the study and had a full understanding that the images differed by changes in OVD. However, they were not informed about the amount of OVD increase represented in each image. Judges were asked the specific question for each slide: "On a scale of 0 to 100, how do you rate the facial naturalness of this image?" and were asked to draw a line on the scale according to their rating of facial esthetics. Judges were allotted 7 seconds for each slide containing a pair of images before automatically transitioning to the next slide (Fig 1). All VAS ratings from part 1 of the study were measured using a 100-mm ruler, rounded to the nearest 0.5-mm


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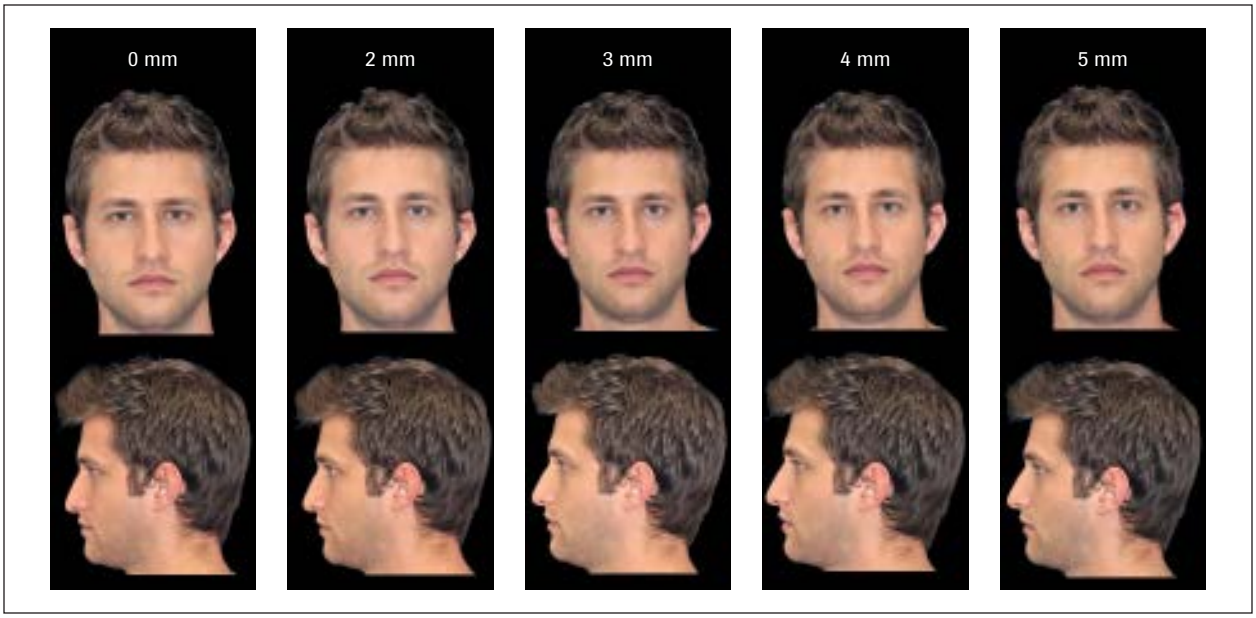


**Fig 1** Image showing example of one of the subjects' set of five frontal and profile photographs that included a baseline image with no overlay and four additional images with mandibular overlays of different thicknesses. For subjective assessments, only one pair of frontal and profile images of the same occlusal vertical dimension (OVD) was presented in each slide for judges.

mark, and documented in an Excel (Microsoft) spreadsheet for further analysis.

For the second part of the study, triangle test was employed to determine the ability of the same judges to correctly identify images with increased OVD. Digital images of the same 10 subjects were presented in the form of a slide show (20 slides). Each slide contained either three facial images or three profile images of the same subject. Among these three images, the OVD of one was increased by 3 mm. The remaining two images were made at baseline (no mandibular overlay). Judges clearly explained that each slide had images of the same subject and that one image was made at an increased OVD (Fig 2). The order of the odd image (increased OVD) was randomized across each slide using a block randomization method. The order of slides was also randomized such that facial and profile images of the same subject were not presented subsequent to one another to avoid the possibility of a recollection bias. Judges were allotted 7 seconds for each slide containing a pair of images before automatically transitioning to the next slide. Each slide show (20 slides) was viewed twice by each judge in a different randomized order. Judges were asked the specific question for each slide, "Of the three images, the OVD of which image is the odd one out?" All data for the triangle test were documented in an Excel (Microsoft) spreadsheet and analyzed for percent correct of total answers.

The data from the two trials for each part of the study were averaged in the form of estimated means and analyzed using SPSS 16.0 (SSPS). Descriptive

**Fig 2** **(a)** One subject's set of three frontal photographs used for triangle test. Each slide contained two images with no overlay and one additional image with a mandibular overlay of 3-mm thickness. In this example, the middle image represents the 3-mm increase in OVD. **(b)** One subject's set of three profile photographs used for triangle test. In this example, the image on the left represents the 3-mm increase in OVD.

statistics were reported as means and SDs. Data were analyzed using the general linear mixed model procedure in SPSS. The mixed model factorial design involved 2 (gender of subject) × 4 (race of subject) × 5 (mandibular overlay thickness) × 2 (trials) within-judges factors, and 1 between-judges factor with two levels (general dentist versus prosthodontist). The first model examined the data as a function of trial only to evaluate the reliability of repeated



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**Table 1** Means and Confidence Intervals for Ratings of Facial Naturalness for All Judges (General Dentists and Prosthodontists)

| Overlay thickness (mm) | Mean rating of VAS (mm) | SE | 95% CI Lower bound | 95% CI Upper bound |
|---|---|---|---|---|
| 0 | 60.2 | 1.0 | 58.2 | 62.3 |
| 2 | 58.1 | 1.0 | 56.0 | 60.1 |
| 3 | 55.6 | 1.0 | 53.6 | 57.5 |
| 4 | 55.0 | 1.0 | 52.9 | 57.1 |
| 5 | 46.9 | 1.1 | 44.7 | 49.1 |

VAS = visual analog scale; SE = standard error; CI = confidence interval.

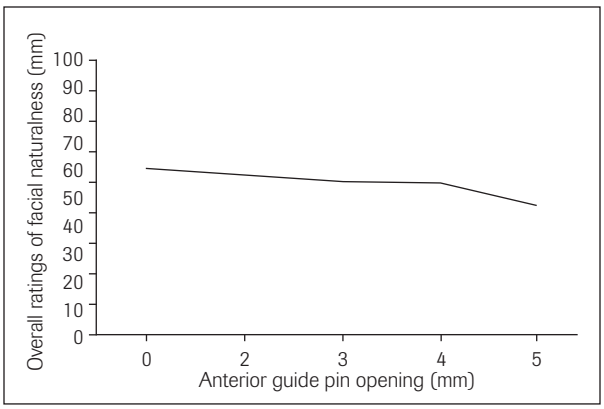


**Fig 3** Plot diagram showing mean visual analog scale (VAS) rating for facial naturalness by all judges for overlays made at various anterior guide pin (AGP) openings of the articulator. The image clearly shows that a 5-mm increase showed significant decrease in VAS ratings.

**Table 2** Pairwise Comparisons of VAS Ratings for All Judges Based on Estimated Marginal Means, for Various Thicknesses of Mandibular Overlays

| (I) Overlay thickness (mm) | (J) Overlay thickness (mm) | *P* | 95% CI Lower bound | 95% CI Upper bound |
|---|---|---|---|---|
| 0 | 2 | .797 | −2.0 | 6.3 |
| | 3 | .013* | 0.59 | 8.7 |
| | 4 | .004* | 1.0 | 9.4 |
| | 5 | .000* | 9.0 | 17.6 |
| 2 | 0 | .797 | −6.3 | 2.0 |
| | 3 | .582 | −1.5 | 6.5 |
| | 4 | .318 | −1.0 | 7.2 |
| | 5 | .000* | 6.8 | 15.4 |
| 3 | 0 | .013* | −8.7 | −0.5 |
| | 2 | .582 | −6.5 | 1.5 |
| | 4 | 1.000 | −3.4 | 4.6 |
| | 5 | .000* | 4.4 | 12.8 |
| 4 | 0 | .004* | −9.4 | −1.0 |
| | 2 | .318 | −7.2 | 1.0 |
| | 3 | 1.000 | −4.6 | 3.4 |
| | 5 | .000* | 3.7 | 12.3 |
| 5 | 0 | .000* | −17.6 | −9.0 |
| | 2 | .000* | −15.4 | −6.8 |
| | 3 | .000* | −12.8 | −4.4 |
| | 4 | .000* | −12.3 | −3.7 |

*Statistically significant at $\alpha = .05$.
CI = confidence interval.

assessments. The next analysis examined the main effects attributable to each of the within-judge factors (subject sex, subject race, and subject mandibular thickness) and the between-judges effect for these factors. Nonsignificant effects for the within-judges factors or the between-judges factor (judge professional status) allowed for that factor to be excluded in succeeding analyses. The final model therefore included all possible interactions of those factors that remained significant in prior analyses. All the factors and interactions were entered simultaneously, and Type III sums of squares were used to evaluate the results. All resulting main effects and interactions were then scrutinized for significance and interpreted at a predetermined alpha value of .05.

As this was a baseline study, findings were predefined as clinically significant if the VAS rating had a 10-mm difference between two measurements and a correctly identified image score of 75% was achieved for the triangle test.

## Results

For the first part of the study, the increase in AGP openings on the articulator showed an inverse relationship to the VAS ratings of the judges for facial naturalness. There was a statistically significant effect on the VAS rating at various AGP openings, of which the most significant decrease was observed at the AGP opening of 4 to 5 mm; subjects wearing the overlay made at 5 mm were consistently rated lower than those at 4 mm by all judges ($P < .05$) (Table 1). Additionally, the difference in mean VAS scores at baseline and with a 5-mm overlay and between the 4- and 5-mm overlays was greater than 10, implying a clinically significant difference based on the predetermined values for this baseline study (Fig 3).

All individual subject and judge factors (race, age, sex) were evaluated using pairwise comparisons and based on estimated marginal means (Table 2). Naturalness ratings of male subjects did not significantly change from 2 to 4 mm but were rated significantly less natural at 5 mm, while female subjects


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began to see decreased VAS ratings from baseline to 2 mm and thereafter for each overlay ($P < .000$) (Fig 4). Subject race and age did not have a statistically significant effect on the judge's ratings. In a pairwise comparison of judge sex, men consistently rated all subjects as less natural than did women at all mandibular thicknesses ($P < .02$). The background of the judge had a small effect on the ratings of facial naturalness. Prosthodontists consistently rated subjects higher (more natural) at all overlay thicknesses compared to general dentists ($P < .008$).

In part 2 of the study, a discriminatory sensory analysis (triangle test) was employed to determine the ability of the judges to correctly identify the images with a 3-mm increase in OVD. In total, judges were able to correctly identify the odd image of the three 57% ± 1% of the time. In a pairwise comparison, the percentage of correctly identified images with increased OVD between prosthodontists and general dentists reflected no significant overall effect. On average, prosthodontists correctly identified the odd image 56% of the time, while general dentists correctly identified 57.3% of the time (Table 3). These numbers failed to reject the null hypothesis of any difference related to judge's background, and were not statistically significant ($P < .582$). Furthermore, they were not clinically significant based on the predetermined score of 75% correct identification as defined in this baseline study. Additionally, Type III sums of squares and test of fixed effects showed no difference in race, sex, or background of the judge in ability to correctly identify the image with a 3-mm increase in OVD.

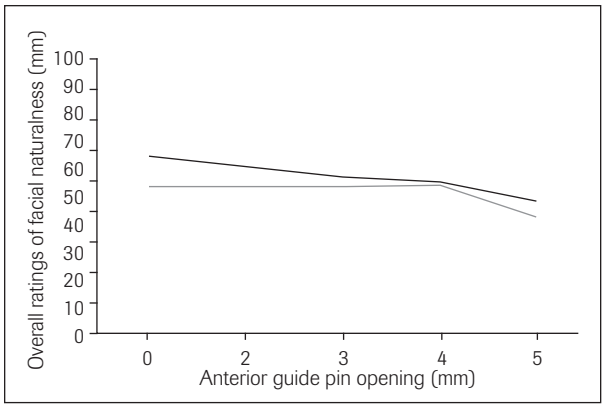


**Fig 4** Plot diagram showing differences in VAS rating of male and female subjects by all judges. The image shows that female subjects' VAS ratings *(top line)* decreased by small increments with each increase in vertical dimension, while male subjects' ratings *(bottom line)* remained relatively unchanged until a 5-mm increase, implying that slight changes in vertical dimension are more likely to be rated lower in females than in males.

**Table 3** Means and Confidence Intervals (CI) for Percent Correct Identification of Image with a 3-mm Increase in OVD for All Judges (General Dentists and Prosthodontists)

| | | | 95% CI | |
|---|---|---|---|---|
| Judge | Mean correct score (%) | SE | Lower bound | Upper bound |
| Prosthodontist | 56.8 | 0.482 | 55.9 | 57.8 |
| General dentist | 57.2 | 0.482 | 56.3 | 58.1 |

SE = standard error.

## Discussion

The null hypothesis of this study was that there would be no difference in the ability of dentists to discern and identify increases in OVD in dentate subjects. This study failed to reject this null hypothesis. This was especially pronounced between 4 and 5 mm in thickness of the overlays. However, the study rejected the null hypothesis that there would be a difference in ability to correctly identify images with a 3-mm increase in OVD based on the judge's background. Incremental opening of the AGP of the semiadjustable articulator was used as a surrogate marker in this study to denote incremental increases in OVD. Mandibular overlays were used to transfer the increases to the oral cavity before being photographed, to minimize the chance of a maxillary overlay affecting lip projection and facial esthetics.

Findings from this study related to VAS ratings contrast with findings from Orenstein et al.[2] In the present study, VAS ratings for facial naturalness showed a linear decrease with incremental increases in OVD, with a statistically significant and clinically significant decrease in ratings from 4- to 5-mm thickness of overlay. Contrastingly, Orenstein et al[2] showed an initial decrease in facial esthetic ratings from 0 to 2 mm, then an increase from 2 to 3 mm, and then a progressive decrease from 3 to 5 mm, all of which were uncorrelated to AGP openings. The most important reason for this difference is related to the nonblinded nature of the present study, where judges were informed in detail about the purpose of the study and knew what to look for when rating the images. On the other hand, general dentists and prosthodontists were unable to differentiate incremental increases in OVD up to 4 mm but unambiguously differentiated the OVD increase at 5 mm. This phenomenon, termed in psychophysics the just noticeable difference (JND), is the minimum amount by which stimulus intensity must be changed to produce a noticeable variation in sensory experience.[7] This may provide confidence to clinicians and patients who may be concerned that OVD increases in



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fixed dental rehabilitations up to 4 mm of opening at the AGP opening of the articulator may unfavorably affect facial esthetics/naturalness. Stated another way, this underscores that clinicians should not increase a patient's OVD in fixed prosthodontic rehabilitations solely to improve facial esthetics. This can significantly affect a patient's treatment plan and may also affect medical-legal considerations.

The triangle test was chosen to satisfy the second objective of the study to test the ability to correctly identify images with increase in OVD. First described by Larmond[4] in 1967, the triangle test is well established, and validated for taste analysis in the food and technology industries. The methodology was updated in 1991 by Poste et al[6] and has been used for many years in human trials of sensory discrimination as it is a simple, reproducible, well established sensory discriminatory test.[6] To the present authors' best knowledge, no studies have previously reported the use of this test in dentistry. In the present study, the image with a 3-mm increase in overlay thickness in each slide was chosen as the discriminator, while the remaining two images were made at baseline (with no overlays). This was done because anecdotally, 3 mm is the most common increase in OVD performed in fixed prosthodontic rehabilitations to gain restorative space, where a 3 mm increase at the AGP of the articulator approximates a 1-mm increase at the molar region due to the arc of closure of the mandible.[8] Other authors have described a clinical ceiling of 5 mm to allow for satisfactory and esthetically appropriate restorations.[9] Findings from the present study showed that although the prosthodontist and general dentist judges knew what to look for, they correctly identified the image with a 3-mm increase in OVD only about 57% of the time. As the predetermined value in this baseline study for correctly identified image score was 75%, this finding was clinically insignificant. However, it can provide more confidence to clinicians and patients that a 3-mm increase in OVD may not be easily identifiable, even to the trained eye.

This investigation made specific improvements to its methodology as compared to previous studies on OVD and facial esthetics; however, some limitations still exist.[2,3,10,11] First, the demographics of the judges were somewhat homogenous because of the geographic limitations of the study. Second, the use of a VAS in rating facial naturalness has inherent limitations related to mental fatigue and compliance.[12–14] However, this scale has been used in numerous studies evaluating facial esthetics within dental and sociopsychologic literature.[15,16] Third, use of triangle test employed images of the same subject side by side, which would never represent assessments made in a clinical environment. This introduces distinction bias when viewing two objects that appear more dissimilar when presented together than separately.[17] However, because this test did not ask for the rating of facial esthetics/naturalness and was simply investigating the JND, the use of this particular assay was justified. Last, both parts of this study involved two trials where judges observed the same photographs twice. This could introduce a contrast effect by enhancing or reducing the perception of a stimulus when compared with a recently observed, contrasting stimuli.[18] For this reason, the results from the two trials were averaged in the form of estimated means; however, the potential for bias still exists. This is the first study providing data on OVD discernment and identification using a nonblinded approach, and the baseline information provided can act as a foundation for future research in larger patient samples with different types of occlusions and facial forms, and for comparing the ways OVD can affect subjective considerations of facial esthetics.

## Conclusions

Based on the findings of the study, a number of conclusions were drawn. There was a linear relationship between VAS ratings for facial naturalness and incremental increase in AGP opening of the articulator using mandibular overlays that was significant at 2, 3, 4, and 5 mm ($P < .000$). The increase at 5-mm overlay thickness was clinically significant based on the predetermined criteria of a 10-mm difference in VAS ratings in this baseline study. The VAS ratings for facial naturalness for female subjects decreased at every incremental increase of OVD, while the same ratings for male subjects decreased only at 5 mm. This suggests slight changes to OVD are more likely to be detected in female subjects than in male subjects ($P < .000$). General dentists and prosthodontists were able to correctly identify the image with a 3-mm increase in OVD 57% of the time. This was clinically insignificant based on the predetermined criteria of 75% set in this baseline study. The race, gender, or background (general dentist or prosthodontist) was not a significant factor in VAS ratings or correct identification of the images with increased OVD.

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