Effect of occlusal vertical dimension on lip positions at smile

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Statement of problem. In complete mouth reconstructive dentistry, the occlusal vertical dimension may be increased to provide adequate restorative space or to improve esthetics. The effect of increasing the occlusal vertical dimension on the smile is not well understood.

Purpose. The purpose of this study was to evaluate the effect of increasing the occlusal vertical dimension on the dimensions of the smile.

Material and methods. Thirty dental students, 12 men and 18 women between the ages of 21 and 30 years old, participated in this study. Polyvinyl siloxane occlusal registrations 2, 4, 6, and 8 mm in thickness were fabricated from articulated stone casts. Posed smile images at occlusal vertical dimension +0, +2, +4, +6, and +8 mm were made with a digital single lens reflex camera mounted on a tripod. A wall-mounted head-positioning device, modified from a cephalometric unit, was used to stabilize the head position. Interlabial gap height, intercommissural width, incisal edge to upper lip, and incisal edge–to–lower lip measurements were made with computer software. The smile index was obtained by dividing width by height. The display zone area was measured by using computer software tracing. One-way repeated measures ANOVA (α=.05) was used for statistical analysis.

Results. With an increase in the occlusal vertical dimension, the interlabial gap height, incisal edge to lower lip distance, and display zone area increased significantly (P<.001), whereas the smile index decreased significantly (P<.001). No significant changes were observed in the intercommissural width and incisal edge to upper lip distance.

Conclusions. The interlabial gap height, incisal edge–to–lower lip distance, and display zone area increase with increased occlusal vertical dimension. The smile index decreases with increased occlusal vertical dimension. However, the width of the smile and the length of the upper lip tend to remain unchanged. (J Prosthet Dent 2014;112:533-539)

Clinical Implications

An increase in the occlusal vertical dimension does not reduce maxillary gingival display or buccal corridor display but shifts the lower lip downward at smile. When an increase in the occlusal vertical dimension is contemplated, care should be taken to match the width-to-height ratio (smile index) to the patient's age.

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For patients who need complex prosthodontic treatment, increasing the occlusal vertical dimension (OVD) may be necessary.[1] Increasing the OVD provides greater interocclusal restorative space and may lessen the need for clinical crown lengthening or endodontic procedures.[2] In addition, increasing the OVD changes the vertical and horizontal overlap relationship of the anterior teeth and may alter facial esthetics in a positive way.[2] The consequences of increasing the OVD have been the subject of debate. Some researchers believe that increasing the OVD is almost always contraindicated, whereas others view it as a variable position that can be adjusted without adverse consequences.[1,3-11] A recent systematic review concluded that increasing the OVD, particularly with fixed restorations, is a predictable and stable procedure.[6] Few studies have looked at esthetic changes after increasing the OVD. Gross et al[9] found that it significantly increased the lower face height. Ushijima et al[12] reported that decreased OVD shifted the stomion and the lower lip in the anterior-superior direction, whereas the upper lip shifted only anteriorly. Mohindra and Bulman[13] evaluated the esthetic effects of dentures made with an increased OVD and found significant improvements in facial esthetics.

Several methods are available for measuring soft tissue dimensions. Direct measurement with rulers or calipers is a simple method but may be susceptible to errors from inadvertent distortion of the soft tissues.[14,15] Photographic analysis with or without facial reference markers has been used by some researchers.[9,16] Video analysis, proposed by Ackerman and Ackerman[17] is popular with orthodontic researchers.[17-20] Another method involves 3-dimensional, noncontact imaging with laser or optical scanners.[12,21] Much research has been done concerning age-related changes of the smile.[18-20] With increasing age, the interlabial gap height (the vertical distance between the upper and lower lips) decreases,[18] the intercommissural width (the distance between the left and right commissures) decreases,[19] and the smile index (width-height) increases.[18] In addition, an increase in the length of the upper lip at smile has been observed.[18-20] These age-related changes have been attributed to increased muscle length, decreased muscle activity, and loss of skin elasticity.[18,19]

The purpose of this study was to evaluate the effect of increased OVD on the dimensions of the smile with respect to interlabial gap height, intercommissural width, incisal edge–to–upper lip distance, incisal edge–to–lower lip distance, smile index, and display zone area. The null hypothesis was that no difference would be found in the various parameters with increased OVD.

MATERIAL AND METHODS

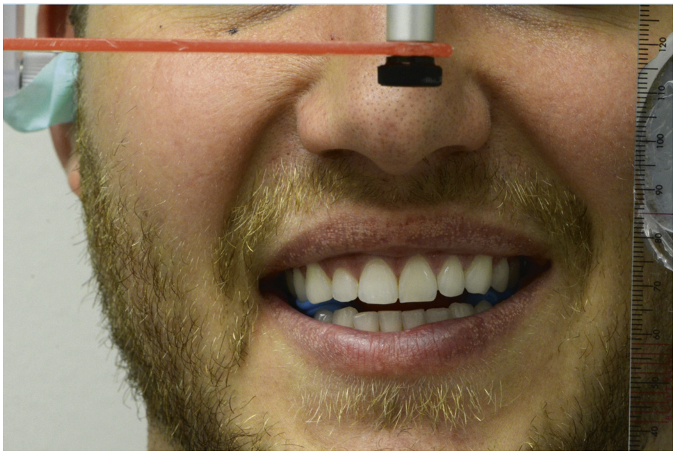
Approval for this study was obtained from the Marquette University School of Dentistry Institutional Review Board (HR-2369). The inclusion criteria for the participants were that they be a dental student or graduate student of the Marquette University School of Dentistry, be between 21 and 39 years of age, be volunteers, have no missing anterior teeth, and have at least 3 teeth in occlusion in both posterior segments. The exclusion criteria were a history of surgery in the facial area; a history of neurologic disorders; a centric occlusion-maximum intercuspation discrepancy >1 mm; an inability or unwillingness to smile; persisting ear infections; an allergy to silicone, nitrile, or irreversible hydrocolloid; or a history of claustrophobia. Thirty dental students, 12 men and 18 women (mean age, 23.8 years; range, 21-30 years) participated in this study. Twenty-one participants had a history of orthodontics (Table I).

TABLE I. Description of study population

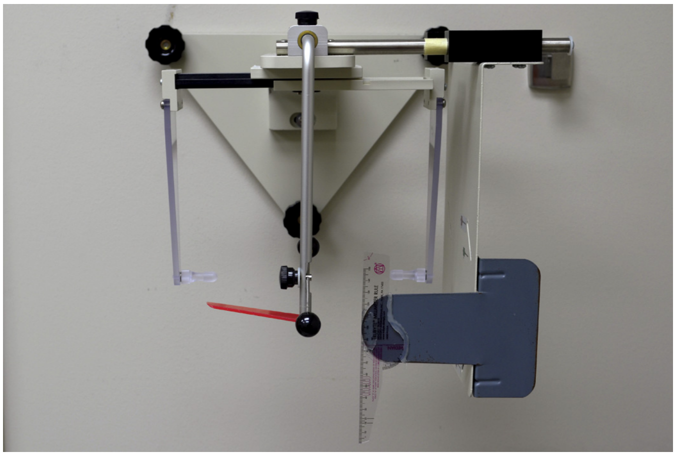
Variable	Value
Age (y), mean (range)	23.8 (21-30)
Sex, no.	
Women	18
Men	12
Race or ethnicity, no.	
White	25
Latino	3
Arabic	1
Asian Indian	1
History of orthodontics, no./total no.	21/30
Angle classification, no.	
Class I	29
Class II	0
Class III	1 (unilateral molar class III)

The study was conducted in 2 sessions. In session 1, irreversible hydrocolloid impressions were made (ImprESSIX Color Change; Dentsply Intl) with metal stock trays (Rim-Lock impression tray; Dentsply). Arbitrary hinge facebow transfers were obtained (Pana-Mount; Panadent). Silicone occlusal registrations in maximum intercuspation also were obtained (Imprint Bite; 3M ESPE). The impressions were disinfected (Cavicide; Kerr TotalCare) and poured into a Type III dental stone (Microstone Golden; Whip Mix Corp). After trimming and indexing, the poured casts were articulated on semiadjustable articulators (PCH; Panadent).

Horizontal lines were drawn approximately 1 mm apical to the gingival margins of the maxillary and mandibular right central incisors. The vertical distance between these 2 lines was measured with a digital caliper (model 500-170; Mitutoyo). This measurement was used to open the articulator by +2, +4, +6, and +8 mm. At these vertical openings, silicone occlusal registration material (Imprint Bite; 3M ESPE) was injected onto the occlusal surfaces from the first premolar to the second molar. These occlusal registrations were used to obtain the desired openings in the OVD. Occlusal registrations at the existing OVD (+0 mm) were not made. The occlusal registrations were trimmed to provide 1-mm-deep indentations of the maxillary cusp tips and coverage up to the gingival margin of the mandibular teeth. The facial half of the maxillary buccal cusp tips were trimmed to permit visualization of complete seating. Coverage up to



1 Representative image (+4-mm occlusal vertical dimension).



2 Head-positioning apparatus.

the gingival margin of the mandibular teeth provided stability and retention of the occlusal registrations in the mouth. The occlusal registrations were disinfected (CaviCide; Kerr TotalCare) and stored in color-coded plastic bags. Because no occlusal registrations were made for the OVD +0-mm group, these plastic bags were left empty.

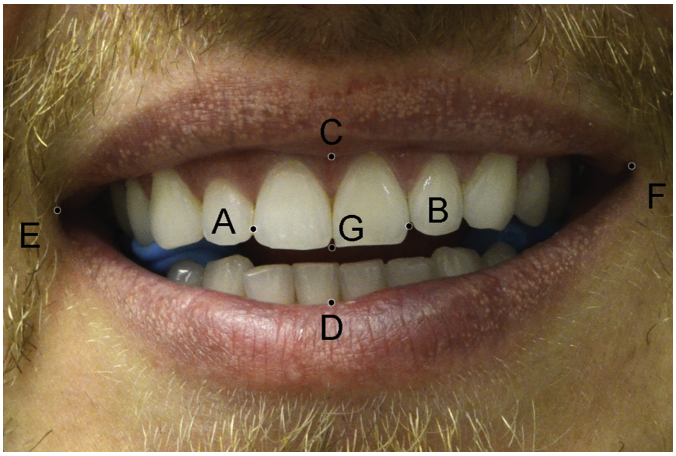
During session 2, three images each were made with the various occlusal registrations in place (Fig. 1). A wall-mounted cephalometric device (Denar Accuceph; Whip Mix Corp) was modified for head positioning (Fig. 2). A right-angle metal plate was attached to the side plate of the head-positioning device, and a plastic ruler was fixed to the end of the metal plate, which allowed the ruler to be set at a fixed distance from the camera. Because participants' faces had varying dimensions, custom orbital pointers of varying lengths were fabricated to permit the orbital pointer to lightly touch the infraorbital notch. After verifying the head tilt, the orbital pointer was moved away from the face to permit uninhibited movement.

A digital single reflex camera (D7000; Nikon) with a macro lens (Micro-NIKKOR 105 mm f/2.8VR; Nikon) was used to acquire photographic data. The camera was mounted on a tripod (055XPROB with 496RC2; Manfrotto). For accurate positioning of the tripod between sessions, the tripod was secured to the floor with a hot glue gun adhesive (GR20K; Stanley Tools). The horizontal and anterior-posterior tilts were checked with a bubble gauge (11990; Stabila). The camera was connected to a laptop computer (Inspiron N5010; Dell) with camera control software (Camera Control Pro 2; Nikon).

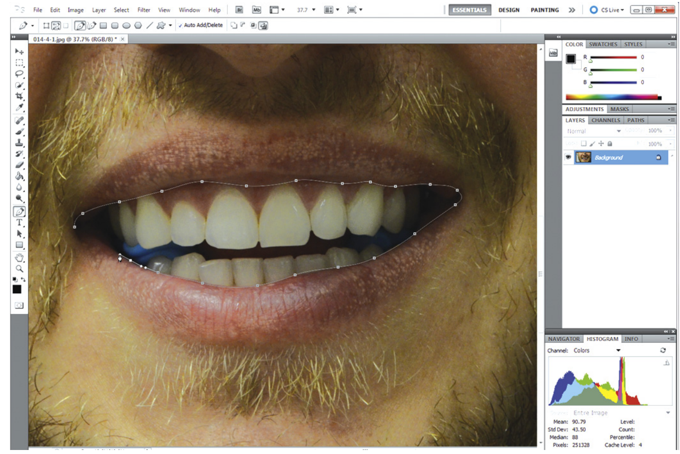
The participant's right infra-orbital notch was marked with a black marker, and the head tilt was subsequently adjusted to this vertical level. Head-tilt readjustment was done for each set of 3 pictures (5 times for each participant). The nasion positioner was not used, so as not to impinge on facial muscles during smiling. The participants were asked to close gently on the back teeth, say, "M, M, M," relax, and smile. An image was then made of the posed smile. The same procedure was repeated 3 times. The order of the placement of the occlusal registrations was randomized by using a list generated from a random number generator (True Random Number Service; RANDOM.ORG <http://www.random.org/>), and the individual groups were referred to as their color codes, instead of the vertical openings, to blind the participants as to which vertical opening was used. At the 0-mm OVD opening, the same instructions were given, but no occlusal registration was in place.

The digital images were imported into software (Photoshop CS5; Adobe Systems), and the following measurements were made: the width of the maxillary central incisors, the interlabial gap height (the vertical distance between the upper and lower lips, which intersects the midpoint of the incisal embrasure between the maxillary central incisors), the intercommissural width (the distance between the left and right commissures), the incisal edge to upper lip distance (the vertical distance between the midpoint of the incisal embrasure and the upper lip), and the incisal edge to lower lip distance (the vertical distance between the midpoint of the incisal embrasure and the lower lip) (Fig. 3). These measurements were made in pixels. To obtain the smile index, intercommissural width measurements were divided by interlabial gap height measurements.

The outline of the border of the display zone was traced with the Pen tool (Photoshop CS5; Adobe Systems), and this area was recorded in pixels (Fig. 4). On the stone cast, the combined width of the maxillary central incisors was measured with a digital caliper and recorded in millimeters to 2 decimal places. This distance was measured 3 times to obtain a mean measurement. The mean measurement in pixels (from 15 images) was divided by the average measurement in millimeters to obtain a conversion ratio for each individual participant. The conversion ratio was used to convert the measurements from pixels to millimeters. For images in which the incisal embrasure was covered by the lower lip, the image was overlaid onto an image with a greater vertical opening (in which the embrasure was not covered) to locate the point of measurement.



3 Points of measurement. (A-B) Width of central incisors. (C-D) Interlabial gap height. (E-F) Intercommisural width. (G-C) Incisal edge to upper lip. (G-D) Incisal edge to lower lip.



4 Display zone area tracing.

One examiner (J.C.) conducted all measurements. These measurements were recorded in a spreadsheet (Excel 2010; Microsoft Corp), and statistical analysis was conducted with software (SPSS 21; IBM Corp). One-way repeated measures ANOVA was used (α=.05). The main effect was occlusal vertical dimension with 5 levels: +0, +2, +4, +6, and +8 mm. If a statistically significant difference was found, then pairwise comparisons were made with Bonferroni corrected paired *t* tests.

RESULTS

The results of this study are shown in Tables II, III. For interlabial gap height, the mean measurement at OVD +0 mm was 10.42 ±3.28 mm. A statistically significant difference (P<.001) was found with increasing OVD. Pairwise comparisons with Bonferroni corrected paired *t* tests revealed all the groups to be significantly different from each other (P<.01 for all pairs). For intercommissural width, the mean measurement at OVD +0 mm was 62.90 ±4.17 mm. No statistically significant difference was found with increasing OVD (P=.352). The mean smile index at OVD +0 mm was 6.58 ±1.92. A statistically significant difference (P<.001) was found with increasing OVD. Pairwise comparisons revealed all groups to be significantly different from each other (P<.01 for all pairs). The average measurement for the incisal edge to upper lip distance at OVD +0 mm was 8.20 ±2.22 mm.

No statistically significant difference was found with increasing OVD (P=.484). For the incisal edge–to–lower lip distance, the mean measurement at OVD +0 mm was 2.28 ± 1.99 mm. A statistically significant difference was found with increasing OVD (P<.001). Pairwise comparisons revealed all groups to be significantly different from each other (P<.01 for all pairs). For the display zone area, the mean measurement at OVD +0 mm was 509.08 ±190.08 mm^2. A statistically significant difference was found with increasing OVD (P<.001). Pairwise comparisons revealed all the groups to be significantly different from each other (P<.01), with the exception of OVD +4 mm compared with OVD +6 mm (P=.064). Lower lip coverage of the incisal embrasure was observed with 5 participants, all of whom were women. For 4 of these 5 participants, lip coverage was seen only at OVD +0 mm, but, in 1 participant, lip coverage was observed at OVD +0 mm and OVD +4 mm.

DISCUSSION

The results support rejection of the null hypotheses that, with increasing OVD, the interlabial gap height, incisal edge to lower lip distance, smile index, and display zone area do not change. However, the results do not support the rejection of the null hypotheses that, with increasing OVD, the intercommissural width and incisal edge–to–upper lip distance do not change. A change of +8 mm in OVD yielded a +5.03-mm change in interlabial gap height and a +5.17-mm change in incisal edge–to–lower lip distance. These findings were similar to findings by Gross et al,[9] who found a +4-mm change in lower face height with a +8-mm change in OVD. This is likely a combination of several factors. First, the change in OVD was measured from the gingival margins. Because the mandible opens on an arc, the measurement is not made perpendicular to the line of sight of the image. This change in angulation may have caused a small discrepancy in the measured vertical distances. The discrepancy magnified as the OVD increased, which yielded less vertical change for each progressive increment of OVD. Second, soft tissue changes are likely to occur to a lesser degree than hard tissue changes. Soncul and Bamber[22] evaluated the soft tissue changes after orthognathic surgical correction of class III deformities and found a 50% to 70% change in upper and lower vermillion borders in comparison with changes in the hard tissue profile. Kamashita et al[23] and Ushijima et al[12] found similar results by using wax rims with variable amounts of lip support and varying OVD.

Tjan et al[24] defined the average smile as one that reveals 75% to 100% of the maxillary anterior teeth and interproximal gingiva. One clinical report claimed

Table II. Results of smile measurements

Measurement/OVD	Mean (SD)	*P* (Greenhouse-Geisser)
Interlabial gap height (mm)		<.001
0	10.42 ±3.28	
2	12.47 ±3.97	
4	13.48 ±4.52	
6	14.35 ±4.37	
8	15.45 ±4.71	
Intercommissural width (mm)		.352
0	62.90 ±4.17	
2	62.54 ±4.47	
4	62.78 ±4.12	
6	62.46 ±4.09	
8	62.22 ±4.50	
Smile index		<.001
0	6.58 ±1.92	
2	5.44 ±1.53	
4	5.11 ±1.53	
6	4.71 ±1.31	
8	4.38 ±1.29	
Incisal edge–upper lip (mm)		.484
0	8.20 ±2.22	
2	8.33 ±2.43	
4	8.19 ±2.49	
6	8.18 ±2.47	
8	8.03 ±2.62	
Incisal edge–lower lip (mm)		<.001
0	2.28 ±1.99	
2	4.14 ±2.52	
4	5.29 ±2.95	
6	6.15 ±2.89	
8	7.45 ±3.40	
Display zone area (mm^2)		<.001
0	509.08 ±190.08	
2	612.61 ±228.35	
4	659.66 ±252.08	
6	696.00 ±244.14	
8	742.94 ±261.52	

OVD, occlusal vertical dimension; SD, standard deviation.

that increasing the OVD decreases excessive gingival display in the smile.[25] However, in the present study, no statistically significant change was found with respect to the upper lip at smile with increasing OVD. The width of the smile affects the width of the buccal corridors, which is a contributing factor to the esthetics of a smile.[26-28] This investigation did not find a significant change in intercommissural width with increasing OVD. This may indicate that the width of the smile is more affected by muscles such as the buccinators, which pull the corners of the mouth laterally, than other muscles of facial expression.[29]

Ackerman and Ackerman[17] described the display zone as the area framed by the upper and lower lips. The display zone area was quantified in the present study by determining the area between the upper and lower lips at smile. A mean (SD) display zone area of 509 ±190 mm^2 was found for the +0-mm OVD group. The high SD indicates a considerable amount of variability in the display zone area among the different participants. A statistically significant increase was found in the display zone area with an increase in the OVD, although no significance was found between the +4-mm OVD and the +6-mm OVD groups. Because the maxillary central incisal edge position is dictated by the maxillary lip in repose,[14] an increase in the display zone area could lead to an increase in the display of the mandibular teeth.

The smile index (width-height) at OVD +0 mm was 6.58 ±1.92. Similar results were obtained by Desai et al,[18] who found an average smile index of 6.73 ±2.09 in the 20 to 29 years old age group. They also found that the smile index increased with age, progressing from 5.63 in the 15- to 19-year-old age group to 8.05 in the 50 years old and older age group. In the present study, an increase in the OVD led to a decrease in the smile index, which progressed from 6.58 at +0-mm OVD to 4.38 at +8-mm OVD. These results indicate that the OVD had a profound effect on the smile index. Clinically, an assessment of the pretreatment smile index compared with age-related average values may help the clinician decide whether the OVD can be increased. For example, increasing the OVD of a 50-year-old patient who presents with a pretreatment smile index of 5.0 may not be prudent because a further decrease in the smile

TABLE III. Results of 1-way repeated measures ANOVA (Greenhouse-Geisser test)

Source	Type III Sum of Squares	*df*	Mean Square	F	*P*
Interlabial gap height (mm)	441.816	2.637	167.572	101.378	<.001
Intercommissural width (mm)	8.697	3.310	2.627	1.110	.352
Smile index	86.647	2.458	35.258	88.231	<.001
Incisal edge–upper lip (mm)	1.344	3.307	0.407	0.841	.484
Incisal edge–lower lip (mm)	466.139	2.287	203.812	115.231	<.001
Internal display zone area (mm^2)	957 855.215	2.805	34151.006	62.685	<.001

index may lead to an unnatural appearance.

In this study, a method that used the width of the maxillary central incisors to calibrate the photographic measurements was used for smile analysis. This method is similar to that of Hu et al[16] who used crown length for calibration. Several recent studies have used videographic techniques to capture a dynamic range of facial movement.[17-20] A photographic technique was selected in this study for its superior image resolution and ease of measurement. One recent study found no significant difference between smiles captured by video and by photographic techniques.[30] In addition, a custom head-positioning device was designed by using a cephalometric unit, similar to a technique described by Ackerman and Ackerman.[17] The millimeter ruler attached to the side plate of the head-positioning device was used to verify the camera positioning and calibration of the photographs. Although the majority of recent studies used the natural head position,[16,18-20] a fixed reference plane (Frankfort Horizontal) was selected in this study to allow for accurate repositioning.

The present study has several limitations. First, the age range of 21 to 30 years may not represent the typical prosthodontic patient. Second, the bulkiness and removable nature of the silicone occlusal registrations may have negatively influenced the smile. In addition, because all of the data were collected in 1 sitting, the long-term adaptation of the facial muscles to an increase in OVD could not be assessed. None of the participants in the present study exhibited any loss of OVD. Patients who have had extensive loss of tooth structure or loss of teeth may behave differently. Further studies are necessary to provide a clear understanding of the long-term clinical implications for the smile of changing the OVD.

CONCLUSIONS

Within the limitations of this study, the following conclusions may be drawn: interlabial gap height, incisal edge to lower lip distance, and display zone area increase with increased OVD; the smile index decreases with increased OVD; a change in the width of the smile should not be expected with an increase in the OVD; and a change in the length of the upper lip at smile should not be expected with an increase in the OVD.

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NOTEWORTHY ABSTRACTS OF THE CURRENT LITERATURE

Influence of abutment-to-fixture design on reliability and failure mode of all-ceramic crown systems

Delben JA, Barão VA, Ferreira MB, da Silva NR, Thompson VP, Assunção WG
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Objective. Evaluate the effect of implant connection designs on reliability and failure modes of screw-retained all-ceramic crowns.

Methods. Central incisor ceramic crowns in zirconia abutments were screwed and torqued down to external hexagon (EH), internal hexagon (IH) and Morse taper (MT) implant systems. Single-load-to-fracture (SLF) test (n=4 per group) determined three step-stress fatigue profiles with specimens assigned in the ratio of 3:2:1. Fatigue test was performed under water at 10 Hz. Use level probability Weibull curves and reliability for missions of 50,000 cycles at 400 N and 200 N were calculated (90% confidence bounds-CB). Weibull probability distribution (90% CB) was plotted (Weibull modulus vs characteristic strength) for comparison between the groups. Fractographic analyses were conducted under polarized-light microscopy and SEM.

Results. Use level Weibull probability calculation indicated that failure was not associated with fatigue in groups EH (β=0.63), IH (β=0.97) and MT (β=0.19). Reliability data for a mission of 50,000 cycles at 400 N revealed significant reliability differences between groups EH (97%), IH (46%) and MT (0.5%) but no significant difference at 200 N between EH (100%) and IH (98%), and IH and MT (89%). Weibull strength distribution (figure) revealed β=13.1/η=561.8 for EH, β=5.8/η=513.4 for IH and β=5.3/η=333.2 for MT. Groups EH and IH exhibited veneer cohesive and adhesive failures. Group IH also presented adhesive failure at zirconia/titanium abutment insert while MT showed fracture at abutment neck.

Significance. Although group EH presented higher reliability and characteristic strength followed by IH and MT, all groups withstood reported mean anterior loads.

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