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Changes in facial soft tissue support with and without a maxillary labial flange.

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Abstract

Purpose: To quantify the effects of a labial flange on upper lip support and facial esthetics in active (high smile) and relaxed (repose) lip positions in maxillary hybrid denture patients.
Materials & Methods: Each research subject had a removable flange fabricated using Aquasil heavy body consistency Polyvinyl Siloxane (PVS). A standardized videography methodology utilizing the 3dMDface.t system was used to capture high smile and repose in research subjects with and without the removable flange. A single 3D frame of each position from both videos (with and without the flange) was captured and saved for further analysis. In order to limit probability of researcher bias, a survey was conducted in which the research subjects, a group of dentists, and a group of laypeople, were shown digital images and asked which they found to be more esthetic, or if they could not tell a difference. The results of the survey were evaluated to confirm proper contour of the removable flanges and absence of researcher bias. High smile frames from each subject, with and without the removable flange, were imported into 3dMDVultus software for quantitative two-dimensional facial analysis using 5 facial anatomic markers: subnasale, labrale superior, stomion, nasolabial angle and lip thickness. Three-dimensional quantitative photometric analysis of facial soft tissue contour was completed on the 3dMDVultus software comparing superimposed images with and without the removable flange at positions of both high smile and repose.
Results: two-dimensional results showed a significant difference in millimeters (mm) with and without a flange for measurement point B (landmark at junction of vertical line of alar border and horizontal line at level of labrale superior) to labrale superior (LS) and measurement of philtrum, (PH) to stomion (STO), with p values of less than 0.05, while the other landmarks did not show a statistically significant difference. Thirteen out of twenty-one landmarks in the three-dimensional analysis showed a statistically significant difference in mm between high smile and repose measured superimposition values with and without a flange, with p values less than 0.03. Research subjects, dentists and laypeople all preferred flange photos overall.
Conclusions: Survey results of the research subjects, dentists and laypeople confirmed that removable flanges were esthetic and negated any researcher bias in their fabrication. These findings suggest a clinically significant difference in the appearance of lip thickness (PH to STO) and projection (B to LS) with and without a labial flange. The results of the three-dimensional analysis show that specific areas of the upper lip are affected more dramatically by a flange when comparing high smile vs repose. Therefore, different facial muscle activation associated with different facial positions has a greater effect on lip support in certain areas, concluding the need for evaluation of lip support at more than just repose (as completed by Bidra et al 2018).

Keywords: upper lip, smile, repose, vestibule, flange

Introduction

Ideal intaglio contours for fixed detachable, or “hybrid” prostheses should be convex to facilitate oral hygiene. While this design has been functionally and esthetically acceptable in mandibular hybrids, maxillary hybrids often require labial flanges to obtain lip support for optimal esthetics, in addition to helping with phonetics/speech. Therein lies the indication for an implant (bar) supported overdenture. In regards to lip support, which can be described as the extent to which the lip is anteriorly positioned by the maxillary incisors and alveolar bone, the deficiency commonly seen could partly be due to the different resorptive patterns: the mandibular ridge becomes broader as it resorbs inferiorly while the maxillary ridge becomes narrower as it resorbs superiorly (Tallgren

1972). However, with the solution of adding a labial/buccal flange, the patient's access to the intaglio surface is no longer adequate for proper peri-implant hygiene procedures (Drago and Howell 2012). Additionally, hygienic maxillary hybrid design often creates a new air distribution pattern during speech. While many patients can phonetically adjust, some patients cannot and require blockage of the air flow between the prosthesis and gingiva in order to obtain acceptable phonetics (Parel 1986). Other factors that play a role in deciding between fixed and overdenture treatment options include interarch restorative space, available bone for number and distribution of implants that can be placed, manual dexterity of the patient for oral hygiene capability, congenital or acquired hard and soft tissue defects, high smile line, location of muscle attachments, and jaw relationships (Angle classification)(DeBoer 1993, Sadowsky 1997, Neves, Mendonça et al. 2004).

Multiple authors present historic solutions to insufficient lip support with fixed hybrid prostheses. One solution to the problem of deficient lip support could be a fixed implant hybrid, with proper convex contours, and a labial flange that can provide lip support while also being removable to maintain hygiene. Earlier literature details a removable gingival veneer made of a heat-curing elastomeric material (Gingivamoll) that helped with lip support and speech but didn't completely resolve issues of food impaction and was unesthetic, especially for patients with a high smile line (Parel 1986). Another example of this treatment is a removable flange made of acrylic that attaches to the maxillary hybrid denture by a ball clasp. For this specific procedure, the decision to incorporate a removable flange needs to be made before fabrication of the final maxillary hybrid prosthesis as the attachment for the ball clasp needs to be processed into the prosthesis (Aparecida de Mattias Sartori, Uhlendorf et al. 2014). An alternative option that could be used if the definitive prosthesis was already processed is the fabrication of a removable flange from Valplast, a pressure-injected nylon thermoplastic resin that would wrap around the labial and buccal superior margins of the prosthesis and snap around the posterior. Both of these methods are valid treatment options that could be further supported by research that shows a quantitative and qualitative difference in lip support with and without a flange, ultimately evaluated by the esthetic satisfaction of the patient.

Previous studies have claimed a labial flange to not be clinically significant at a position of repose, quantitatively or esthetically (Bidra, Manzotti et al. 2018, Bidra, Nguyen et al. 2018, Bidra, Touloumi et al. 2018, Bidra, Zapata et al. 2018). However, no literature objectively or subjectively measures differences between a flange and flangeless presentation of a patient in any other position than repose. While patients may spend most of their time in repose, one might be most self-conscious of their appearance in times of animation. Therefore, it is important to determine if there is a statistically significant difference in lip support and thus, patient appearance, when smiling. The purpose of this study is to quantify the effects of a labial flange on lip support and facial esthetics in an active (high smile) and relaxed (repose) lip position in maxillary hybrid denture patients. The null hypothesis is that lip support in high smile does not demonstrate a statistically significant quantitative difference with or without a flange when compared to repose.

Materials and Methods

Human subject approval for this study was obtained from the 59MDW Institutional Review Board (FWH20190001H).

Removable flange fabrication: Each research subject (20 total) had a provisional removable flange fabricated using Polyvinyl Siloxane (PVS). This was completed by injecting Aquasil Ultra Heavy

Regular Set PVS into the maxillary vestibule and shaping the impression material in the same manner as border molding for a complete maxillary denture impression. The remaining PVS material was then removed upon complete set and excess trimmed away (Figure 1). The new PVS moulage was placed into the research subject's mouth and evaluated for comfort and appropriate labial support. Each provisional removable flange was be made by the same provider (the author) so that consistency in technique is maintained across all research subjects. Once the removable flange fulfilled the standards of the provider, a board-certified prosthodontist examined the research subject and evaluated the lip support to make sure it had proper contour.

Video capture: A standardized videography methodology was used to capture high smile and repose in research subjects with and without the removable flange. The videography set up placed the research subjects at a standardized distance allowing the 3dMDface.t camera system to optimally capture the subject from ear to ear. Subjects were sitting upright, in a neutral head position with eyes looking straight toward the camera at the level of the horizon. The research subjects wore a pair of sunglasses to make their likeness unidentifiable. These glasses were secured using an interocclusal bite registration material (Regisil PB) slightly superior to the nasion in addition to a strap pulled tight around the back of their head. These sunglasses also had five fiducial markers made of gutta percha that served as fixed set points for image superimposition (Figure 2).

Research subjects were then instructed to practice moving from repose to high smile. To verify the accuracy of the subject's high smile they were shown to touch their finger to their face just below their eye at the level of the orbitale and instructed to contract the muscle they are touching while smiling (Robbins 2016). After practicing this movement 3 times the 3dMDface.t system was then utilized to capture a 5 second video (producing 35-3D frames at 7 frames per second) of the research subject going from repose to high smile without the removable flange, remembering their practiced movement and muscle contraction without actually holding their finger to their face. Another 5 second video was captured in the same manner except with the research subject wearing the removable flange. Both videos were then played back and the 3D frames analyzed from a facial view to track exactly when the research subject was at their highest smile, and also at a position of repose. The primary investigator then determined when the research subject achieved their true high smile and repose and a single 3D frame of each position from both videos (with and without the flange) was captured and saved as a .tsb file for further analysis.

Survey:
In order to limit the probability of researcher bias, a survey was conducted in which the research subject, a group of dentists, and a group of laypeople were shown digital images (explained below) and asked which they find to be more esthetic, or if they cannot tell a difference. Images made included frontal and profile views, with and without the flange, in high smile and repose, for a total of 8 images. Only two images were shown on a single screen at a time comparing flange vs flangeless at the different positions (high smile and repose) and views (frontal and profile) with photos having the flange vs without in a pre-set order that changed which side of the screen the flange was on (Figures 2 & 3). The survey participants were blinded as to which images include a flange and which did not. The research subjects, 20 dentists and 20 laypeople responses were asked which of the two photos on the screen they found to be more esthetic or if they could not

tell a difference, and their responses recorded in an excel spreadsheet. The research subjects were shown 4 slides of their own photographs for a total of 8 images. Dentists and laypeople were shown a variety of research subjects in a standard presentation of 10 slides, 5 at a position of repose and 5 at a position of high smile, in no particular order. The results of the survey were evaluated to contribute to confirmation or denial of proper contour of the removable flanges.

2D image analysis: High smile frames from each subject, with and without the removable flange, were imported into 3dMDVultus software for quantitative facial analysis. Once imported, 5 facial anatomic markers: subnasale, labrale superior, stomion, nasolabial angle, and lip thickness, were identified using standard anatomic and anthropometric definitions (Figure 4). All measurements taken for this analysis were made in millimeters. Frontal and profile 2D images were obtained from the same 190-degree 3D frame previously captured from the 3dMDface.t system video. The 3D frames in high smile, one with and one without the flange, were then rotated to view straight on with eyes at the level of the horizon for the 2D image analysis and then rotated to a sagittal view to produce a profile 2D image.

On the profile images, two points were marked at the anterior-most point of the nose (pronasale-PN) and at the alar border of the nose to establish horizontal naso-labial boundary ("X") as a constant variable (Bidra, Zapata et al. 2018). Three more points were then marked at the subnasale (SN), labrale superior (LS), and stomion (STO) with their distance to the alar boundary labeled as A, B, and C, respectively (Figure 4). Three ratios were then calculated, A/X, B/X, and C/X, to represent projection of the maxillary lip at 3 points. Another measurement involved points marked at the anterior inferior border of the columella, the soft tissue subnasale, and the labrale superior. The angle at which lines drawn from the columella to subnasale and subnasale to labral superior intersect provides the nasolabial angle (NLA). The difference in these ratios with and without a removable flange would show any changes in lip support.

On the frontal images, two points were marked at the subnasale and stomion with the distance between defined as the vertical nasolabial boundary and labeled as constant variable ("Y") (Bidra, Zapata et al. 2018). Another point was marked connecting the two superior-most points of cupid's bow and its distance from the stomion labeled as ("D") (Figure 5). A ratio was calculated for thickness of the lip (D/Y) and compared with and without the removable flange. (Bidra, Zapata et al. 2018) An analysis on lip projection in high smile, with and without the removable flange, comparing length from the visible vermillion border to stomion, was done by comparing the "D" measurements made previously.

3D linear and volumetric analysis: As an expansion upon existing sources (Gordner 2017) exploring quantitative 3D photometric analysis of facial soft tissue contour, the high smile 3D frames both with and without the removable flange were superimposed onto each other (3dMDVultus). The same steps were repeated with the repose 3D frames, with and without the removable flange (Gordner 2017). These images were superimposed in a standardized manner by matching up the fiducial points on both 3D data sets. Accuracy in overlay/superimposition of images was monitored by root mean square (RMS) error through 3dMDVultus software. RMS error, defined as the variation between two surfaces at a specific area, is considered acceptable when less than 0.5mm (3dMD 2007).

On each of the superimposed images, high smile and repose, a series of points were identified and labeled using the 3dMDVultus software. The first 3 landmark points were placed at the midline with the first at the subnasale, second at the superior aspect of cupid's bow, and the third halfway in-between the first two points in the center of the philtrum. Then, from each of these 3 landmark points, 3 additional points were added laterally on both the right and left at spatial increments of 12mm. For data collection purposes, each of the 21 points were labeled with a letter, starting at the research subject's right most superior point labeled as "A", continuing across the row ending at the research subject's left most superior point as "G" and picking up again at the research subject's right second row with "H" and continuing in the same fashion (Figure 6). Once these points are marked in the software for linear analysis, any quantitative difference between the images without the flange compared to the superimposed image with the flange was shown at that specific point in millimeters. These labeled facial points and quantitative measurements that were calculated within the 3dMDVultus software were recorded and saved for a paired t-test analysis. The goal of this statistical analysis was to evaluate changes in lip support that occur with and without a flange and compare these changes at repose and high smile at 21 different landmarks on the upper lip.

Results

Survey results of research subject evaluating their own images in profile and frontal in both repose and high smile revealed they considered the photo with the flange to be more esthetic 54.41% of the time, no flange 32.35% of the time and were not able to tell a difference 13.24% of time (Table 1). When a standardized series of photos in both positions at frontal and repose were shown to a group of 20 dentists and 20 laypeople, similar results occurred. Dentists chose the flange photo 51.5%, no flange 31.5% and were not able to tell a difference 17% of the time. Laypeople chose the flange 44.5%, no flange 39.5% and no difference 16% of the time. Calculated confidence intervals supported that a flange was preferred by all 3 survey audience groups.

Paired t-test results of the two-dimensional data with a p-value less than 0.05 being statistically significant revealed B to STO (lip projection) and PH to STO (lip thickness) both having statistically significant differences when comparing with and without a flange at high smile (Table 2). The three other two-dimensional landmarks did not show a statistically significant difference at a position of high smile.

Calculated RMS values for the superimposed images were all less than 0.5, which by manufacturer's instructions (3dMDVultus) verifies an accurate alignment.

Results of the three-dimensional analysis paired t-test with a p-value less than 0.02 being statistically significant revealed a statistically significant change in lip support at 13 of 21 landmarks on the upper lip in high smile vs a more neutral position of repose (Table 3). Landmarks with statistical significance were located primarily to the first and third row of grid lines labeled as points A, B, C, E, F, G, H, N, P, Q, R, S, and T (Figure 6).

Discussion

Survey data verified flange fabrication did not add bias to the quantitative analysis aspects of this study as the photo with the flange was chosen more often than without a flange or no difference.

Although statistically significant, differences in lip projection and lip thickness among flange and no flange groups were less than 0.5mm. Consistent with Bidra et al. 2018 this small of a difference may not be clinically significant. However, comparing the location of the significant differences between that article and this research demonstrate important differences between facial positions. Data reported in Bidra et al. 2018 showed statistically significant differences in nasolabial angle (NLA) and subnasale at repose, while this research at high smile shows statistically significant differences at labrale superior (lip projection) and frontal lip thickness (PH to STO). The finding from this study suggests, in contrary to the opinion in Bidra et al. 2018, that high smile affects upper lip position differently than repose, and therefore validates the need to consider both positions when evaluating the need for a flange.

Thirteen of twenty-one landmarks used for the three-dimensional analysis showed statistically significant differences when comparing high smile and repose measured differences between superimposed images (with and without a flange). The measured differences range from 0.5 to 1.2mm and while those individual differences are once again minimal, the overall effect of more than half of the landmarks having a significant difference validates the importance of verifying lip support at high smile and repose.

Conclusion

Statistically significant changes in lip projection and thickness were found at high smile with and without a flange. There were also statistically significant differences in changes of lip support comparing high smile and repose at 13 of 21 landmarks between. These findings reject the null hypothesis that high smile does not demonstrate a statistically significant quantitative difference with or without a flange when compared to repose.

In conclusion, the results of this study, including comparisons made to previous studies (Bidra et.al. 2018), indicate the importance of evaluating multiple facial positions and factors clinically before deciding for or against a flange.

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Tables

Survey audience	Flange	No flange	No difference	CI 95% preferred flange vs not
Research Subjects	54.41%	32.35%	13.24%	54.4% ±11.8% (42.6-66.2%)
Dentists	51.50%	31.50%	17%	51.5% ±6.9% (44.6-58.4%)
Laypeople	44.50%	39.50%	16%	44.5% ±6.9% (37.6-51.4%)

Table 1: Survey results show the percentage of time that the respective survey audiences preferred the photo with or without a flange, or if they could not tell a difference between the two photos. All three survey audiences chose flange photos more often on average, thus confirming that flange contours were esthetic and fabricated without bias.

Variable	N	Hybrid with a flange (Mean ± SD) (mm)	Hybrid without a flange (Mean ± SD) (mm)	Mean difference ± SD flange versus flangeless (mm)	p-value
Subnasale (a/x)	22	0.569 ±0.173	0.576 ±0.195	-0.007 ±0.158	0.827
Labrale superior (b/x)	22	0.495 ±0.111	0.449 ±0.106	0.046 ±0.080	0.014
Stomion (c/x)	22	0.351 ±0.116	0.330 ±0.112	0.020 ±0.063	0.145
Nasolabial angle (in degrees)	22	102.855 ±14.741	104.341 ±15.830	-1.486 ±7.324	0.352
Frontal lip thickness (d/y)	22	0.362 ±0.105	0.340 ±0.092	0.022 ±0.040	0.019

a/x - The ratio of the distance from alar border to subnasale divided by the distance from alar border to pronosale.

b/x - The ratio of the distance from alar border to labrale superior divided by the distance from the alar border to pronasale.

c/x - The ratio of the distance from alar border to stomion divided by the distance from alar border to pronasale.

d/y - The ratio of the distance from a horizontal line connecting the 2 superior most points of cupid's bow to stomion, divided by the distance from the subnasale to stomion.

Table 2: Analysis of two dimensional images with and without a flange at 5 anatomic markers using a paired t-test. Differences were statistically significant only for labrale superior and frontal lip thickness, but with less than 0.5mm difference.

Variable (landmark)	N	Difference with & without flange (mm)		Mean difference with & without flange ± SD between repose & high smile (mm)	p-value
		Repose	Smile		
A	22	1.095	0.455	0.64 ±0.675	0.01
B	22	1.864	0.706	1.158 ±0.708	0.01
C	22	1.393	0.815	0.578 ±0.641	0.01
D	22	0.914	0.738	0.176 ±0.951	0.396
E	22	1.5	0.914	0.587 ±0.495	0.01
F	22	1.87	0.803	1.067 ±0.655	0.01
G	22	1.256	0.381	0.875 ±0.719	0.01
H	22	1.128	0.459	0.669 ±0.677	0.01
I	22	1.379	1.112	0.267 ±0.858	0.159
J	22	1.248	1.399	-0.151 ±0.799	0.386
K	22	1.228	1.577	-0.349 ±0.797	0.053
L	22	1.324	1.605	-0.281 ±0.596	0.038
M	22	1.439	1.203	0.236 ±0.443	0.021
N	22	1.141	0.353	0.789 ±0.458	0.01
O	22	0.514	0.65	-0.137 ±0.642	0.329
P	22	0.424	1.042	-0.618 ±0.809	0.01
Q	22	0.513	1.213	-0.700 ±0.572	0.01
R	22	0.501	1.213	-0.712 ±0.602	0.01
S	22	0.481	1.378	-0.897 ±0.581	0.01
T	22	0.41	1.097	-0.687 ±0.683	0.01
U	22	0.443	0.602	-0.159 ±0.504	0.154

Table 3: Analysis of superimposed three dimensional images showing difference in mm between flange and no flange at positions of repose and high smile. Paired t-test results show mean difference between repose and high smile superimposed images, with statistically significant values for 13 of the 21 landmarks, validating the importance of evaluating flange appearance at both repose and high smile.

Figures

Figure 1: Removable flange made with Aquasil heavy-body consistency polyvinyl siloxane.

Figure 2: Frontal images in repose with patient wearing removable flange on left and without flange on right.

Figure 3: Profile images in repose with patient without flange on left and wearing removable flange on right.

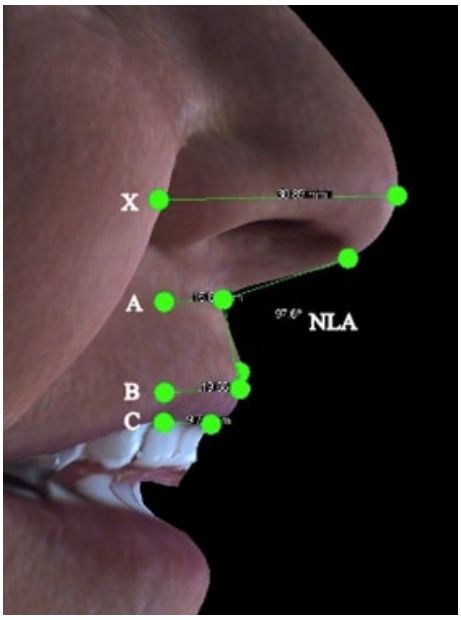

Figure 4: Profile two-dimensional analysis landmarks: X – pronasale to alar border, A – subnasale to alar border, B – labrale superior to alar border, C – stomion to alar border, NLA – nasolabial angle.

Figure 5: Frontal two-dimensional analysis landmarks: Y- subnasle to stomion, D - superior point of cupids bow to stomion.

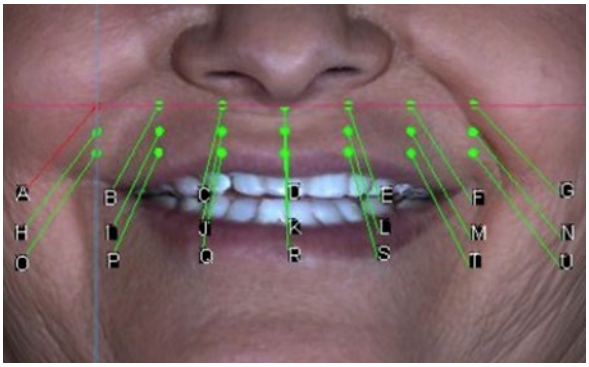

Figure 6: Frontal three-dimensional analysis landmarks labeled A-U.