COMPARATIVE ANALYSIS OF PHONETIC TESTS USED FOR ASSESSING THE SMILE DISPLAY

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Abstract
Aim. To comparatively analyze different phonetic tests used for assessing smile display, i.e. pronunciation of "ee" phoneme, "chee", "cheese", "Chester eats cheesecake by the Chesapeake". Methods. Registrations were made using videography. Subjects were placed sited, instructed to hold their head in a natural position, and asked to repeat five consecutive times each of the four phonetic tests, whose order was randomized. For horizontal display maximal intercommissural width was evaluated, and for vertical display the distance between stomion superius and the maximal incisal edge was analyzed. Results. Nineteen participants were included, 8 males and 11 females, aged 24 to 29 years old (mean 25 years). During speech, maximal horizontal display was observed while pronouncing "ee" phoneme, and maximal vertical display while saying "chee". While smiling, maximal horizontal and vertical display were rather similar for all four previously used phonetic tests. Paired t-test revealed that for all four named phonetic tests, during speech compared to a posed smile, the horizontal display was statistically significant reduced (the difference ranged from .65 to 1.56 of the width of the right central maxillary incisor) and maximal vertical display was rather similar. Conclusions. The mentioned phonetic tests seem more appropriate for the analysis of vertical smile display than for the horizontal smile display, for the latter a correction coefficient being most probably necessary. The use of a phonetic test followed by a posed social smile may positively contribute, through this "functional exercise", to obtaining a more natural outcome by decreasing the variability of the social smile acknowledged when using static methods.
Keywords: dental, aesthetics, dynamic smile analysis, videography, teeth visibility

Introduction

In the last decades, aesthetic dentistry has grown importance, probably as an adaptation to the increased interest accorded to physical appearance in human social interaction, and as a response to patient's request who rather frequently demands a "perfect smile" (1-3). Nowadays, for the dental practitioner obtaining an esthetic and functional outcome seems to be of equal importance. For delivering dental treatments in accordance to patient's needs and expectations, considering the esthetic outcome, an accurate evaluation of static and dynamic position of dento-facial composition is recommended (4). It is well acknowledged so far the fact that speech, through the use of phonetic tests, is a useful diagnostic tool in smile analysis, though still lacking agreement on which test is the most accurate (5;6). Clarification of these aspects is clinically relevant for treatment planning or monitoring of a wide range of dental treatments of various specialties, e.g., orthodontic or prosthodontic ones, or by means of conducting research that needs a more accurate method of evaluation of the smile display (7-9).

The aim of this study was to comparatively analyze different phonetic tests described to be used for assessing smile display, i.e. pronunciation of "ee" phoneme, "chee", "cheese", "Chester eats cheesecake by the Chesapeake". Both width and height display were considered during speech and posed smile, horizontal display being evaluated through the maximal intercommissural width and vertical display being measured through the distance between stomion superius and the maxillary incisal edge.

Methods

Study design and participants. A cross-sectional study was designed and implemented on dental students from "Carol Davila" University of Medicine and Pharmacy, Bucharest. Volunteer dental students were enrolled from April to May 2014. Participants were considered eligible if they were aged 20 to 30 years old, if they were of Romanian citizenship with an average-high English knowledge. Most of Romanian dental students have basic knowledge of English, it being used during their training through high school and primary university years. Subjects were excluded if they had undergone previous orthodontic or prosthetic treatment, in regard to the fact that these interventions might have interfered with tooth positioning and therefore with natural teeth exposure during speech and smile, if they presented severe malocclusion or soft tissue alterations (e.g., cleft lip) - supposedly corresponding to other situations then the normal or if they presented phonetic disorders.

All participants were informed upon the main characteristics of this study and a written informed consent was granted. The research reported in the paper was undertaken in compliance with the Helsinki Declaration on Human Rights. The Ethics Committee of the "Carol Davila" University of Medicine and Pharmacy, Bucharest, reviewed and approved the study protocol (PO-35-F-03; No 72).

Study variables and data collection. The main study outcomes were maximal intercommissural width, for assessment of the horizontal display (1) and maximal distance from stomion superius to the maxillary incisal edge, for assessing vertical display (2), during phonation and posed smile (Figure 1).

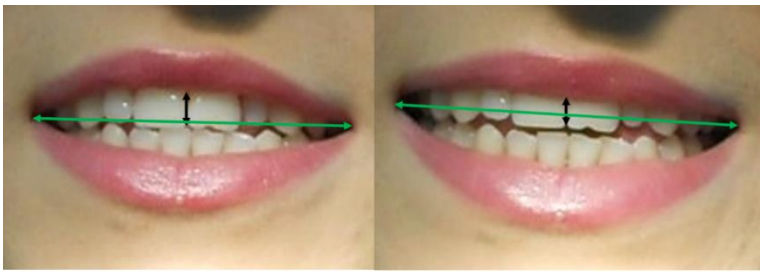

Figure 1. Main study outcomes

These were registered through the use of several phonetic tests, described to be used for assessing the smile display, namely:

T1 phonetic test – "ee", i.e., prolonged, sharped articulation of "e" sound;
T2 phonetic test – "chee";
T3 phonetic test – "cheese";

T4 phonetic test – "Chester eats cheesecake by the Chesapeake".

Registrations were made using videography. Digital video clips of the subjects who agreed to participate in this study were taken using a digital video camera (Nikon COOLPIX L27). Subjects were placed sited and instructed to hold their head in a natural position. Camera lens were placed parallel to the apparent occlusal plane, on a fixed prop, at a focal distance that ranged from 53 cm to 57 cm. Only the lower third of the face was captured.

The subjects were asked to clearly say their name, than to lift their upper lip for a full exposure of the central incisor and then to repeat five consecutive times each of the four phonetic tests mentioned above. After the pronunciation of each test the subject was instructed to relax, then smile and then to relax again. Therefore, for each subject forty registrations were made, i.e. five registrations of the phonetic display for each of the four phonetic tests used, and five registrations of the smile display after the four phonetic tests used. The order of the tests were randomized by using a sequence generated at random.org website. Before each phonetic test, one member of the team with high English knowledge (i.e., Ana Hagiu) exemplified the pronunciation of the respective phonetic test, and the subject could see the respective phonetic test written in big letters on an A4 sheet of paper held in front of him/her during articulating time.

The video clip was downloaded and was partitioned in .jpeg frames through the use of Scenalyzer Live software 4.0.These frames were used as a support for the measurements using Adobe Photoshop CS2. They were analyzed for identifying the frames which best corresponded to maximal horizontal and vertical display during speech and posed smile.

Maximal intercommissural width, as a measure for horizontal display, was registered during speech and while smiling for all tests. The ratio between the maximal intercommissural width and the maximal width of the right central maxillary incisor was recorded. The mean value of the five registrations made for each test for each subject was recorded and used in the data analysis.

Maximal distance from stomion superius to the maxillary incisor edge, as a measure for vertical display, was registered during speech and while smiling for all tests. The ratio between the maximal distance from stomion superius to maxillary incisal edge and height of the right central maxillary incisor was recorded. The mean value of the five registrations made for each test for each subject was registered and used for analysis.

Data analysis. Repeated ANOVA measures were performed to compare transverse and vertical display when using each of the four mentioned phonetic tests during speech, respectively smiling. When data violated the assumption of sphericity, a Greenhouse-Geisser correction was used. Post-hoc Bonferroni statistical analysis was performed.

Paired t-test was used for comparing horizontal and vertical display during speech and while smiling for the four phonetic test used.

SPSS Statistics for Windows was used to perform the statistical analysis. Significance was set at $p<0.05$ (significance level 95%) for all statistical tests.

Results

Nineteen participants were included in the study sample, gender distribution being 8 males and 11 females, aged 24 to 29 years old (mean 25 years).

Speech display according to the four phonetic tests used. During speech, maximal horizontal display, measured by maximal intercommissural width, was observed while using T1 phonetic test (i.e., "ee"), and, maximal vertical display, measured by maximal distance from stomion superius to maxillary incisal edge, was observed using T2 phonetic test (i.e., "chee"). Repeated ANOVA measures determined that there were statistically significant differences between the four phonetic tests used. A post hoc Bonferroni statistical analysis showed that the maximal horizontal display was significantly higher

by the usage of T1 phonetic test compared to T3 and T4 phonetic tests, but T1 and T2 phonetic tests were not statistically significant different from each other. Thus, usage of shorter tests (T1 and T2) seemed more appropriate for dynamic analysis of maximal horizontal display during speech (Table 1).

Table 1. Speech display according to the four phonetic tests used

	maximal horizontal display				**maximal vertical display**			
test	mean	SD			mean	SD		
T1	6.05	.76	F(3, 54)=6.46, p=.001*		.75	.16	F(2.05, 0.01)=5.41, p=.008*	
T2	5.75	.96			.85	.09		
T3	5.46	.69			.83	.09		
T4	5.28	.63			.79	.11		
Bonferroni statistical analysis								
comparison	mean difference	std. error	95% CI lower	95% CI upper	mean difference	std. error	95% CI lower	95% CI upper
T1 vs. T2	.30	.23	-.40	.99	-.11*	.03	-.21	-.00
T1 vs. T3	.58*	.19	.03	1.15	-.08	.03	-.18	.02
T1 vs. T4	.77*	.16	.27	1.25	-.04	.03	-.14	.06
T2 vs. T3	.29	.21	-.34	.92	.03	.02	-.03	.08
T2 vs. T4	.47	.18	-.06	1.00	.06*	.02	.01	.12
T3 vs. T4	.19	.14	-.22	.59	.04	.02	-.03	.11

T1- “ee”; T2 - “chee”; T3- “cheese”; T4 – “Chester eats cheesecake by the Chesapeake”
* p<0.05

Smile display according to the four phonetic tests used. While smiling, maximal horizontal and vertical display was rather similar for all four previously used phonetic tests. Repeated ANOVA measures determined that the smile display was not statistically significant different after the usage of the named four phonetic tests (Table 2).

Table 2. Smile display according to the four phonetic tests used

	maximal horizontal display			**maximal vertical display**		
test	mean	SD		mean	SD	
T1	6.70	.61		.81	.13	
T2	6.81	.55	F(2.26, 40.59)= 0.56, p=0.593	.83	.17	F(3, 54)= 1.43, p=0.243
T3	6.84	.60		.80	.08	
T4	6.84	.60		.84	.09	

T1- “ee”; T2 - “chee”; T3- “cheese”; T4 – “Chester eats cheesecake by the Chesapeake”

Speech vs. smile display for the four phonetic tests used. Paired t-test revealed that for all four named phonetic tests, horizontal display was statistically significantly reduced during speech compared to a posed smile, the difference being rather variable according to the four named statistical test used (ranging from .65 to 1.56 of the width of the right central maxillary incisor). The maximal vertical

display was less variable between speech and posed smile, the difference between them being statistically significant only for T1 phonetic test, i.e., prolonged pronunciation "e" phoneme (Table 3).

Table 3. Speech vs. smile display for the four phonetic tests used

maximal horizontal display						
test	mean difference	std. error	95% CI lower	upper	t	p
T1	-.65	.10	-.87	-.44	-6.37	<0.001*
T2	-1.07	.15	-1.38	-.75	-7.04	<0.001*
T3	-1.35	.15	-1.68	-1.02	-8.60	<0.001*
T4	-1.56	.12	-1.82	-1.30	-12.76	<0.001*
maximal vertical display						
test	mean difference	std. error	95% CI lower	upper	t	p
T1	-.06	.02	-.11	-.01	-2.63	.017*
T2	.02	.02	-.02	.06	1.26	.224
T3	.02	.02	-.02	.07	1.08	.292
T4	-.05	.02	-.10	.00	-2.02	.058

T1- "ee"; T2 - "chee"; T3- "cheese"; T4 – "Chester eats cheesecake by the Chesapeake"
* $p<0.05$

DISCUSSION

By the usage of different phonetic tests, different phonetic display of the oral structures was found, maximal in the horizontal dimension by saying "ee" sound, and maximal in the vertical dimension by "chee" articulation. Horizontal display was found to be statistically significant reduced in phonation compared to a posed smile, with a mean difference of .65 to 1.56 of the width of right maxillary incisor, depending on the phonetic test used. Even so, vertical display was found to be rather similar in phonation and posed smile with a mean difference of .02 to .06 in height of the right central incisor. Therefore, phonetic tests can be regarded as being more appropriate to be used for assessing vertical smile display, than for the horizontal smile display.

In accordance with the increased interest for the esthetic outcome of the dental treatment, growing preoccupation is aimed towards identifying more accurate methods of examination, relevant to the "smile design". Smile capturing and examination by the usage of static photographs is the most often used but it is suggested to bring rather insufficient data, with somewhat questionable reliability (10). Dynamic smile analysis through videography is seen as an improved method for smile evaluation through which a more predictable, standardized smile is attained (11). The method described by Ackerman et al., uses different phonetic tests, followed by a posed social smile (10;12;13). Even so, it isn't clearly stated which phonetic test is the most accurate, differences regarding the smile display among them being suggested.

The use of the four named phonetic tests in this study was decided considering the fact that they are all known as methods used for the smile analysis. Phonetically they all seemed based on the "e" sound, used singular or in different constructions with various length, and with different positioning of this phoneme, i.e, "e" preceded by a consonant ("chee"); "e" in the middle of a word ("cheese"); "e" repeated several times throughout a sentence, positioned in the

beginning, in the middle and in the end of a word ("Chester eats cheesecake by the Chesapeake"). By the usage of different phonetic construction based on "e" sound, different display of the oral structure during speech, in both horizontal and vertical dimension, was observed, as expected, and it can be related to the change of lips dynamics during pronunciation. Even so, similar parameters of the after smile display were obtained, regardless of the previous phonetic test used. Considering that smile display is wider than speech display, according to this study's results all test can be used previous to a posed smile, suggesting the fact that the longer one ("Chester eats cheesecake by the Chesapeake") relates to the widest afterwards posed smile, in both horizontal and vertical dimension.

Phonetic tests are described as a diagnostic tool in smile analysis, suggesting the fact that during speech and while smiling similar oral structure display is obtained, speech-based methods being more recommended than static methods due to their higher reliability. From this perspective, our research is concordant with some previously made, that found a statistically significant difference between horizontal display during speech and smile (10). This study's results suggest that the bigger the length of the word or of the phrase the smaller is the transversal display during speech, regardless of the number of times the "e" sound is repeated through the phonetic construction. Even so, our results suggest that it is possible to use horizontal speech display as an indicator of horizontal smile display, but most probable a correction is needed, that is variable in accordance with the phonetic test used. Vertical display during speech and smile were found to be rather similar in this study, suggesting that it is more accurate to evaluate them by the usage of "chee" or "cheese" phonetic tests. These results are partially disagreeing with some previous researches. According to Ackerman et al. between pronunciation of "cheese" and a posed smile there is a difference in maximum incisor exposure of about .70±1.31 mm (10). According to Yaghoubzadeh, in the 20-29 age group, between pronunciation of "Chester eats cheesecake by the Chesapeake" and a posed smile there is a difference of .94 mm (5). One can observe that, similar to our results, those studies report a reduced difference of vertical display between speech and smile, usually less than 1 mm, which can be considered clinically acceptable when establishing smile height. Also, these aspects are probably influenced by other factors that should be counted, such as age. Even so, speech analysis may be relevant for the esthetic analysis in all age-groups, considering that age-related effects seem to be less obvious in situations where more muscular activity is required, e.g. the lip line height changes less during smiling compared to the natural rest position (14).

Considering that smile is one of the most critical facial expressions, with impact on a personal and social level, dental treatments should include an accurate evaluations of patient's features, relevant for smile design (15;16). Dental practitioners should acknowledge that for the patients, and most probably for themself also, esthetic ratings are both subjective and objective. Therefore, treatment planning in restorative dentistry may be recommended to be firstly established based on esthetic principles considering objective method of evaluation, followed by changes based on patient's subjective perception, in order to reach an agreement and obtain an esthetical rehabilitation that meets patient's needs and expectations (17; 18).

When discussing study limitations it is important to mention the fact that participants were not native English speakers, this could mean certain pronunciation discrepancies. Another limitation could be the transfer from the mobile recording through the use of the digital camera to the frame, e.g., framing could generate shape distortions. Additionally, future studies on a larger sample size can confirm if indeed horizontal display during speech can be used for assessing smile display by the usage of a correction coefficient, and if the difference

of vertical display during speech and smile is indeed slightly reduced and can be considered clinically acceptable.

Conclusions

While smiling, compared to speaking, there seemed to be observed rather similar vertical display, but increased horizontal display of the oral structures. Phonetic tests seems more appropriate to be used for the analysis of vertical smile display than for the horizontal smile display, for the latter a correction coefficient being most probably necessary. Also, for acknowledgement of maximal horizontal and vertical display, different phonetically tests seems to be best indicated, namely "ee" for the horizontal display, and respectively "chee" for the vertical display. The usage of a phonetic test followed by a posed social smile may positively contribute, through this "functional exercise", to obtaining a more natural outcome by the decrease of the variability of social smile acknowledged when static methods are used.

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