ORIGINAL ARTICLE

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The acceptability of variations in smile arc and buccal corridor space

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Structured Abstract

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Objectives – To evaluate the esthetic acceptability range of computer-generated variations in smile arc and buccal corridor.

Design – Web-based descriptive study using available subjects.

Setting and Sample Population – The World Wide Web. Subjects for the main study included 115 lay and 131 orthodontist raters.

Experimental Variables – Buccal corridors and smile arcs, each presented for a female and a male image. Buccal corridors were presented as none, ideal and excessive. The smile arc was presented as flat, ideal and excessive. The nine male and female variations, as combinations of the above variables, were each presented twice to evaluate reliability.

Outcome Measure – Acceptability of buccal corridors and smile arcs using the web-based instrument. An arbitrary super majority threshold of acceptability was set at 67% approval.

Results – Both laypersons and orthodontists showed good reliability ($k \geq 0.70$). There was a broad range of acceptability, but laypersons and orthodontists showed no significant differences on the two variables tested. While orthodontists and laypersons both found smiles with excessive buccal corridors to be significantly less acceptable than those with ideal or absent buccal corridors, they were still acceptable over 70% of the time. Flat smile arcs were only acceptable 50–60% of the time, while smiles with ideal and excessive smile arcs were significantly more acceptable 84–95% of the time. When examining buccal corridors and smile arcs together, excessive buccal corridors were significantly less acceptable than ideal or absent buccal corridors regardless of the smile arc. A flat smile arc significantly reduced the acceptability of any buccal corridor to below the threshold of acceptability.

Conclusions – Laypersons and orthodontists have similar preferences when acceptability of buccal corridors and smile arcs are considered. Flat smile arcs are more detrimental to smile esthetics than variations in buccal corridors. Clinicians must realize that although attractiveness may be reduced by variations in buccal corridors and smile arcs, the result may still be acceptable to a majority of people.

Key words: buccal corridor; computer-assisted; esthetics; image processing; orthodontics; smile arc; smiling

Introduction

Facial and dental esthetics have become increasingly important during the last decade when considering diagnosis and treatment planning. Recently, the field of orthodontics has experienced a 'paradigm shift' to focus more on esthetics, with specific emphasis on soft tissues around the mouth (1, 2). Although many current theories and clinical practices have evolved from anecdotal evidence or from restorative dentistry concepts, new data are emerging related to the science of esthetics. Two aspects of esthetics have recently received great attention: smile arc and buccal corridor space.

Frush and Fisher (3) were among the first to publish the concept of smile arc. Hulsey (4) quantified the smile line as a ratio to the lower lip. He found the smile line to be an important contributing factor to an attractive smile and suggested that orthodontics affects the smile line by adversely flattening it. Ackerman et al. (5) retitled the term 'smile line' to 'smile arc.'

Frush and Fisher (3) identified the notion of buccal corridor spaces. By definition, buccal corridor spaces were the negative space created between the buccal surfaces of the posterior teeth and the inner wall of the cheek. Too much buccal corridor resulted in large empty spaces, while too little looked artificial and was considered the essence of bad prosthetic denture esthetics. Some orthodontists currently advocate maxillary expansion in the absence of cross bites in an attempt to reduce buccal corridor space (6). Hulsey (4), on the other hand, found that buccal corridor spaces did not contribute significantly to smile esthetics. This finding was recently confirmed by Ritter et al. (7).

With the evolution of digital imaging, manipulation and testing of esthetic variables can be accomplished in a reliable and quantifiable manner. Kokich et al. (8) used variations of smile esthetics with a computer-based approach and found that orthodontists, general dentists, and lay people had varying levels at which they detected dental discrepancies.

Computer simulations of buccal corridor spaces have been studied and validate Hulsey's (4) original findings. Using modified cropped smiles to display absent and large buccal corridor spaces, which were then rated on a visual analog scale, it was concluded that buccal corridor spaces did not have an effect on the smile ratings of orthodontists, general dentists, and lay people (9). Recently it was found that laypersons could differentiate between different percentages of buccal corridor (10). When laypersons were shown full face color photographs with five alterations in buccal corridor, they preferred faces with minimal buccal corridor spaces. Laypersons were able to distinguish changes in buccal corridor on all levels except when they became minimal. Laypersons preferred broad smiles significantly more than narrow smiles.

Parekh et al. (11) evaluated the clinical impact of smile esthetics using digital images and attractiveness scores rated on a visual analog scale. They found all smile arcs with absent and ideal buccal corridors were rated nearly identically for males and females, while excessive buccal corridors brought all ratings down. For both genders flat smile arcs overwhelmed the attractiveness of all buccal corridors and were rated in the lower 40% of the scale. Orthodontists, especially female orthodontists, used a greater range of the rating instrument than laypersons. Buccal corridors and smile arcs generally made less difference to laypersons than to orthodontists. All raters, regardless of buccal corridors, generally preferred ideal smile arcs over excessive smile arcs and excessive smile arcs over flat smile arcs. In a somewhat similar study regarding buccal corridors, again using digitally modified images, there was a significant preference for minimal buccal corridors as rated by laypersons and orthodontists (12). This study demonstrated no differences based on the age or gender of the raters or between laypersons and orthodontists.

This new era of computer-generated images provides great opportunities for orthodontic esthetic research. Extremely realistic images, indistinguishable from actual clinical images, can have a single or combination of variables modified in precise and repeatable ways so that a range of variation can be proposed. Because manipulation of the images can be carried out in multiple ways, mastery of the techniques can provide images that accomplish the variations in clinically meaningful ways (e.g. if lip length is the variable of interest, it can be changed while holding the teeth constant, but if alveolar height is the variable of interest, it can be altered while holding the lip constant). As the technology and operator skills mature, it is becoming possible to provide a nearly continuous range for each variable instead of discrete, non-continuous variables. The vehicle for presentation can be cropped to display a precise portion of the face and teeth so the context and perspective of the obser-

vation is always identical. Subtle differences can be introduced by layering effects so that identical presentations can portray both genders. All these options with this level of precision are unachievable with conventional clinical photography.

Understanding attractiveness of the smile arc and buccal corridor space is important, because it provides a hierarchy of esthetic preference. This approach does have the weakness that practitioners can become infatuated with statistical and possibly suspect clinical differences. Detected differences can be viewed as critical thresholds that are then mistakenly applied to the clinical setting. Another way to look at the issue of smile esthetics is to ask where the boundaries of acceptability reside. This may be a more forgiving and realistic approach that allows more latitude and more accurately describes critical limits for clinical orthodontics. One might rate an esthetic variation as lower and less attractive on a scale, but still find the appearance acceptable.

The purpose of this study was to determine the range of variation orthodontists and laypersons found esthetically acceptable regarding smile arc and buccal corridors using male and female computer-generated and modified images of the circum-oral area. The null hypotheses for this study were that there were no significant differences: among the buccal corridors, among the smile arcs, among buccal corridors and smile arcs when considered together or for image or rater gender.

Materials and methods

The details of the method, including illustrations, with the exception of the question pertaining to acceptability, have been published previously (11). A summary is presented here to familiarize the reader with the general method.

Image manipulation

Following IRB (explain abbreviation) approval, frontal digital images of ideally aligned teeth, and esthetic lips from different patients were obtained. These images were modified using Adobe Photoshop® 7.0 (San Jose, CA, USA) to create bilaterally symmetrical teeth and a set of lips. The teeth were morphed to progressively modify the curvature of the incisal edges to fit 12 parabolic curves. The lips were modified so that the lower lip would coincide with one of the middle level curves. An ideal smile arc and lips were combined to form the ideal composite smile with all teeth displayed to the maxillary second molar. Airbrushing created seven different sizes of buccal corridors. A 'male' image was created with an overlay of facial hair.

Pilot survey

Pilot and pilot follow-up reliability surveys were administered to experienced orthodontists (at least 5 years post-residency) in order to set the standards for the ideal smile arc, the maximum acceptable accentuated smile arc, the ideal buccal corridor (i.e. the ideal amount of black space) and an excessive buccal corridor (i.e. too much black space) for male and female images. The surveys were administered using Quask^{TM} Form Artist (New Canaan, CT, USA). The orthodontists chose their preferred response for smile arc and buccal corridors using emoticons, which are interactive sliding bars that display a changing picture when the slider is activated.

Main survey

Raters voluntarily provided demographic information including gender, US geographical region, ethnic background, highest level of education completed, and any dental affiliation. Orthodontists were asked for the year they completed their professional training. If the rater was a layperson, they were asked to choose their income bracket from a drop down list. Available laypersons were contacted with conscious effort not to include those with dental affiliations.

The sample of raters consisted of 115 laypersons (60 males and 55 females) and 131 orthodontists (116 males and 15 females). On average, orthodontists were 22 years post-residency. The lay raters could be typified as college educated, Caucasian and from the central US with a median income of $50 000 to $75 000.

Median values from the pilot survey were used to create images for the main study that were presented using Quask^{TM} Form Artist. Flat smile arcs and absent buccal corridors were available by definition. The ideal smile arc chosen by the pilot raters (arc #7) was constructed in such a way that the incisal edges of the

maxillary teeth tracked the lower lip and matched the definition of the ideal smile arc. The excessive smile arc (arc #10 of 12) was selected as the next arc beyond the one chosen by the raters as the maximum acceptable arc. Buccal corridor was calculated as difference between visible maxillary dentition width and inner commissure width divided by inner commissure width and reported as a percentage. The ideal buccal corridors chosen were 6% and 11% while the excessive buccal corridors were 14% and 19% both for the females and males, respectively.

The smile arc variations (flat, ideal, excessive) were combined with the buccal corridor variations (none, ideal, excessive) to create nine female and nine male images combinations. Fig. 1 illustrates the composite male smiles.

The raters were asked to denote whether the displayed smile was acceptable or not (Fig. 2). Raters were asked to evaluate the nine female and nine male smiles twice in order to determine reliability for a total of 36 smiles. The survey was designed such that the 36 smiles were randomized each time the survey was taken.

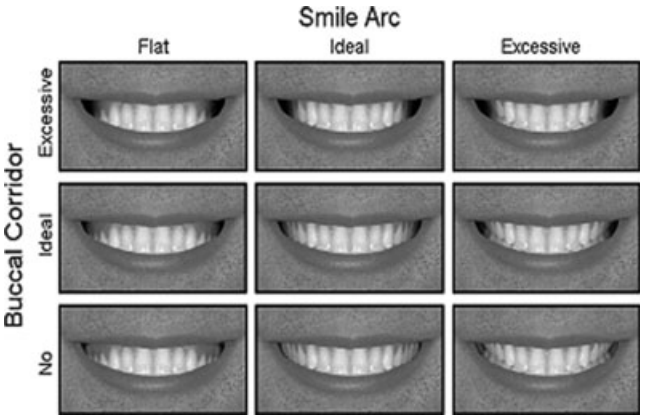

Fig. 1. Smile variations in buccal corridors (BC) and smile arcs (SA) as raters judged for male images.

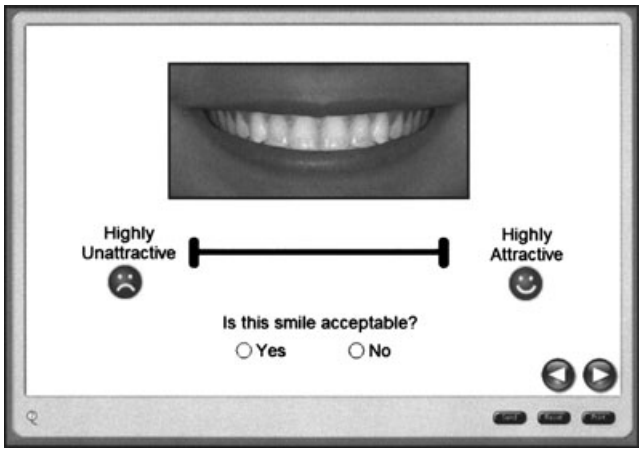

Fig. 2. This screen from the main survey requested the raters to judge the smile as acceptable or unacceptable.

Statistical analysis

Simple Kappa statistics with 95% confidence intervals was used to test the reliability of the main survey. Two logistic regression models were used to evaluate image acceptability. The first model (all occupations model, which included both orthodontists and laypersons) utilized rater group, buccal corridor, and smile arc, as the independent variables. Due to a paucity of female orthodontists in our sample, a second model (lay model) was generated utilizing only laypersons, which showed reasonable gender balance among the raters (60 males and 55 females), to examine the following independent variables: buccal corridor, smile arc, image gender and rater gender. Both models employed the generalized estimating equation to adjust for repeated measures. Post hoc comparisons were made using multiple McNemar tests which were adjusted using the step-down Bonferroni method of Holm (13). The level of significance was set at a $p < 0.05$ for all analyses.

Results

Reliability

Orthodontists showed good reliability ($\kappa = 0.79$, lower 95% confidence bound (LCB) = 0.76, upper 95% confidence bound (UCB) = 0.83) and laypersons showed fair reliability ($\kappa = 0.70$, LCB = 0.66, UCB = 0.73).

Acceptability

Acceptability represents a range of attractiveness measures and encompasses what is acceptable to a certain percentage of the population. For the purposes of this study the acceptability threshold was set at 67%, which although arbitrary is clearly beyond a simple majority and appears to represent a clear or super majority. This type of threshold was used to define acceptability because clear demarcations of acceptability were desired rather than relying on the possibility of nearly equal opinions which can be derived from simple majorities.

All-occupations model

The all-occupations model logistic regression showed significant effects for the following interactions: group by corridor ($p = 0.01$), group by smile ($p = 0.001$), and corridor by smile ($p = 0.0001$). Orthodontist and laypersons found absent buccal corridors and ideal buccal corridors statistically more acceptable than excessive buccal corridors, but excessive buccal corridors were acceptable to over 70% of the raters (Fig. 3). There were no statistical differences between the ratings of the orthodontists and the laypersons.

Orthodontists and the laypersons found the ideal and excessive smile arcs statistically more acceptable than the flat smile arc. Laypersons also found the ideal smile arc statistically more acceptable than the excessive smile arc. All ratings for the ideal and excessive smile arcs were 84–95%, while those for the flat smile arc ranged from 50% to 60% (Fig. 4). There were no statistical differences between the ratings of the orthodontists and the laypersons.

Figure 5 summarizes the interactions of all raters when judging the acceptability of the combinations of smile arc and buccal corridor variations. When considering the acceptability of buccal corridors and smile arcs, these data are quite clear that none of the buccal corridors are acceptable for flat smile arcs, while all buccal corridors are highly acceptable for ideal and excessive smile arcs (but the acceptability of the excessive buccal corridors was significantly less than ideal or no buccal corridors for each smile arc). The acceptability for the flat smile arcs fell under the acceptability threshold of 67%. Differences between buccal corridors across smile arcs were statistically significant in every instance except for ideal and excessive smile arcs with an excessive buccal corridor.

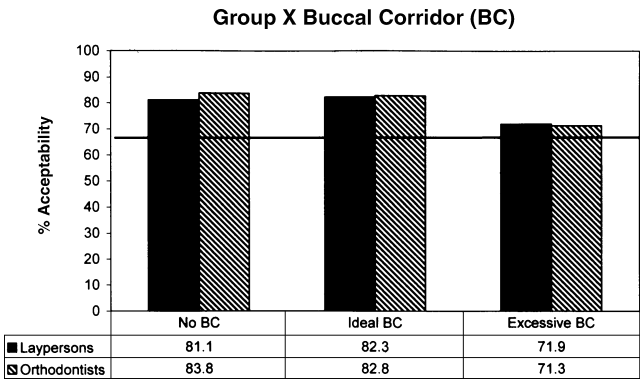

Fig. 3. Acceptability ratings by orthodontists and laypersons for buccal corridors. The bold horizontal line represents the supermajority threshold for acceptability. For both orthodontists and laypersons the excessive buccal corridor (BC) was rated statistically significantly ($p = 0.003$) lower than either ideal or no BC.

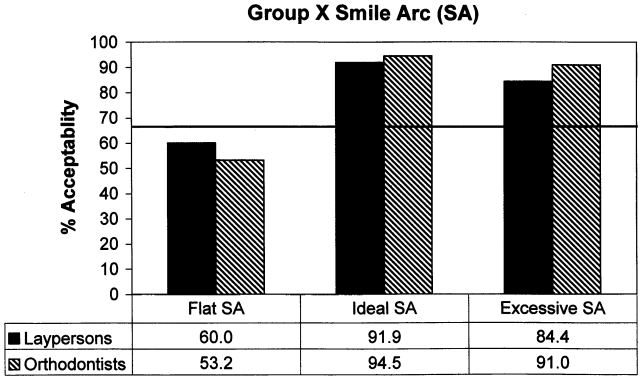

Fig. 4. Acceptability ratings by orthodontists and laypersons for smile arc. The bold horizontal line represents the supermajority threshold for acceptability. For both orthodontists and laypersons there were statistically significant differences ($p = 0.007$) between all smile arcs except between ideal and excessive smile arc (SA) for orthodontists.

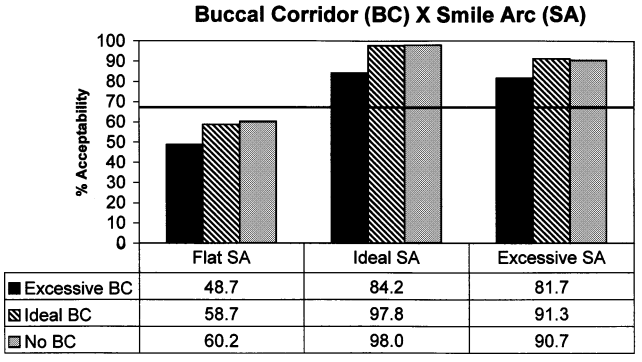

Fig. 5. Acceptability ratings by all raters for the interactions of buccal corridors and smile arcs. The bold horizontal line represents the supermajority threshold for acceptability. Within a given smile arc there were statistically significant differences ($p = 0.003$) between all buccal corridors except ideal BC and no BC. There were also statistically significant differences ($p = 0.003$) between all buccal corridors for smile arcs except between excessive BC for ideal and excessive SA.

Lay model

The lay logistic regression model revealed significant effects ($p < 0.0001$) only for smile arc with none of the other main effects or interactions reaching significance. Specifically, there were no significant differences for image or rater gender. The smile arc as judged by laypersons was significantly different for each variant (flat, ideal and excessive $p < 0.0005$) but the flat arc was judged less acceptable and below the 67% level (Fig. 6).

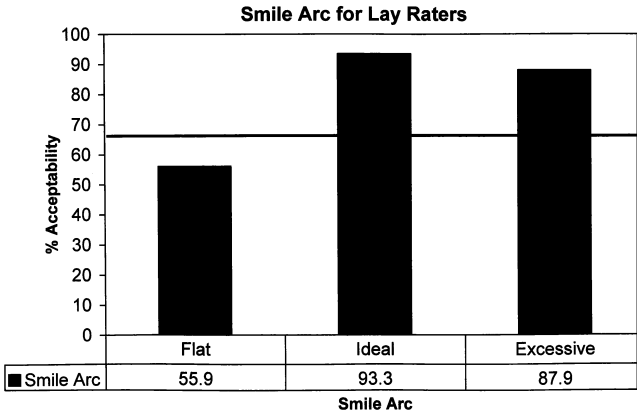

Fig. 6. Acceptability ratings by laypersons for smile arc when including image and rater gender in the logistic regression model. The bold horizontal line represents the supermajority threshold for acceptability. There were statistically significant differences among all smile arcs $p < 0.0005$.

Discussion

Using acceptability measures asks a different question than attractiveness ratings. Observers may have quite distinct opinions regarding their preferences for attractiveness that separate different esthetic variables into statistically significant entities. These dramatic attractiveness differences can be seen in a more moderate light when patients consider what is acceptable. This more forgiving attribute may have more applicability and provide the practitioner with more flexibility, especially when patients have not been sensitized to minor discrepancies.

Laypersons and orthodontist viewed acceptability of buccal corridors and smile arcs similarly in this study. Parekh et al. (11) previously reported no clinically significant differences between lay and orthodontic raters for attractiveness. Roden-Johnson et al. (9) found no differences among rater groups for buccal corridors space, which is also consistent with the findings of Ritter et al. (7) and Gracco et al. (12). To this point, similarities of opinion regarding buccal corridor space among rater groups is a common finding.

Because the orthodontic raters were not equally distributed between gender their gender preferences could not be contrasted. Laypersons, on the other hand, were nearly equally distributed for gender in the sample; however, their rater preferences were not different as a function of rater or image gender. The attractiveness findings of Parekh et al. (11) were similar with the exception of a clinically significant dislike of excessive buccal corridors in males with ideal smile arcs. Moore et al. (10) also found no significant differences between ratings for males and females or by male or female raters. Gracco et al. (12) recently confirmed that rater gender and age were not significant in rater judgments of buccal corridor preferences.

Overall, excessive buccal corridors emerged as less acceptable, but remained in the highly acceptable range. Hulsey (4) and Ritter et al. (7) found buccal corridors not to be an esthetic issue. Roden-Johnson et al. (9) also found, using different criteria, that buccal corridor size was not a critical issue. The attractiveness data of Parekh et al. (11) indicated raters preference for minimal buccal corridors, and excessive buccal corridors were not clinically significantly less attractive except in males with ideal smile arcs. Moore et al. (10) found differences between the narrow and broad smiles as determined by proportion of buccal corridor space. Gracco et al. (12) found a preference for minimal buccal corridor space. Apparently people do prefer less buccal corridor space, but substantial variation is acceptable.

On the other hand, flat smile arcs were significantly and decidedly less acceptable than other smile arcs for all raters. Flat smile arcs did not meet the threshold for acceptability. Although minor distinctions existed between ideal and excessive smile arcs, these are highly acceptable for all raters. Few studies have tried to quantify the esthetics of the smile arc. The attractiveness data from Parekh et al. (11) parallel the low acceptability for flat smile arcs. This finding is consistent with Hulsey's (4) warning that flat smile arcs are unesthetic.

Synergisms were present when looking at the combined effects of variations of smile arcs and buccal corridors. While excessive buccal corridors reduce the acceptability of all smile arcs, the most dramatic impact was from flattening the smile arc on any buccal corridor. That single change moved the results, regardless of the buccal corridor space, to the unacceptable range.

When observing the responses between the pilot and main surveys, it is particularly interesting to focus on the orthodontists. In the pilot surveys, orthodontists were asked to determine thresholds at which smile arcs and buccal corridors became excessive. One would expect smile characteristics falling within the non-ideal or excessive range as determined by the pilot studies to be unacceptable to orthodontists in the main study.

This was not the case. In fact, excessive buccal corridors were acceptable over 71% of the time and excessive smile arcs were acceptable over 91% of the time. This variation may be due to the nature of the survey instrument; the pilot study used a dynamic image that allowed for direct comparisons, where the main study used randomly displayed static images that did not allow for direct comparison. Variation in responses may also be attributed to the relatively smaller sample size in the pilot surveys as well as the distribution of responses in the pilot study. In addition, the pilot surveys were one-dimensional and did not account for synergistic effects between smile arc and buccal corridors.

With the great attention given to buccal corridor dimensions and proportions in the orthodontic literature, it is important to know that the smile arc is a much more substantial factor in smile esthetics. It is also critical to know that there is great latitude with most variants of smile arc and buccal corridor except when the arc is flattened.

Conclusions

1 While excessive buccal corridors are rated as less acceptable than ideal and absent buccal corridors, they are still acceptable over 70% of the time.

2 Flat smile arcs, regardless of buccal corridor, display are only acceptable 50–60% of the time and are not acceptable to laypersons.

3 Ideal smile and excessive smile arcs, regardless of buccal corridor display, are acceptable 84–95% of the time.

4 Rater or image gender do not appear to play a role in acceptability for smile arc and buccal corridors when evaluated by laypersons.

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