Orthodontic Appliance Preferences of Children and Adolescents

Thesis

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ABSTRACT

Although attractiveness and acceptability of orthodontic appliances have been rated by adults for themselves and adolescents, children and adolescents have not provided any substantial data. **Objective:** To evaluate children and adolescent preferences and acceptability of orthodontic appliances. **Methods:** Images of orthodontic appliances previously captured and standardized for the research of Zuichkovski et al and Rosvall et al were selected and incorporated into a computer-based survey. Additional images of shaped brackets and colored elastomeric ties, as well as discolored clear elastomeric ties were captured and incorporated onto existing survey images with Adobe® Photoshop®. The survey displayed twelve orthodontic appliance variations to 135 children (n=45 of each 9-11 years, 12-14 years, 15-17 years). Subjects rated each image for attractiveness on a visual analog scale (VAS) and acceptability (yes/no). All images were displayed and rated twice to assess rater reliability. **Results:** Overall reliability for attractiveness rating was r=0.74 and k=0.66 for acceptability. There were significant differences in bracket attractiveness and acceptability in each age group. The highest rated appliances were clear aligners, twin brackets with colored ties, and shaped brackets with and without colored ties. Colored elastomeric ties improved attractiveness significantly over brackets without colored ties for children 12-14 years. There was a tendency for older subjects to rate clear orthodontic appliances higher than younger subjects. Ceramic brackets with discolored ties tended to be rated lower than ceramic brackets with new ties, and scored lowest in acceptability and attractiveness in all age groups. Female subjects rated shaped brackets significantly higher than male subjects. **Conclusions:** The results of this research demonstrate that children's preference for orthodontic appliances differs by age and gender. Child and adolescent preferences differ from adult preferences.

Dedicated to my family

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CHAPTER 1

INTRODUCTION

Recently, the orthodontic market has experienced phenomenal growth in the development and production of orthodontic appliances that are designed to appeal to the patient consumer. Traditionally, the options for bracket style or appliance design were considerably limited for both the patient and provider. However, a shifting paradigm toward dental esthetics[1], increased demand for orthodontic treatment[2], consumer driven desire of esthetic treatment alternatives, and a competitive orthodontic industry and profession have all contributed to the development and production of alternative orthodontic appliances and new bracket styles[3, 4]. Orthodontic patients and practitioners are now presented with a variety of treatment options previously unavailable.

Just as each orthodontic appliance is unique in its esthetic qualities, each also has biomechanical benefits and potential limitations. For a practitioner providing bracket options for patients, selecting which bracket to offer becomes a function of both esthetics and functionality--what will be esthetically acceptable to the patient and clinically efficient for the doctor.. Though many studies have sought to compare and quantify the clinical efficiency of bracket systems, few studies have investigated the patient perception of appliance esthetics. Ziuchkovski et al evaluated the attractiveness and acceptability of traditional, ceramic, self-ligating, and lingual braces, as well as clear aligners in adult subjects[5]. Rosvall et al evaluated an expanded set of bracket options and included an assessment of the value of esthetic appliances to consumers[6]. Both studies surveyed only adult subjects 18 years and older. Although in one aspect of the study the adults were asked whether the presented appliances would be considered acceptable for use

on their children, there are no published data to show how children and teenagers themselves perceive these same appliances. Other factors may also influence a child's preference, for example, the interaction of colored elastomeric ties on traditional metal brackets, the effect of discolored clear elastomeric ties on ceramic brackets and the option of alternative bracket shapes designed more specifically for children.

Evaluating these bracket variables to determine preference and acceptability in children and adolescents could gauge the demand for various appliances in these age groups and could serve as a baseline to assess future changes.

COMPREHENSIVE LITERATURE REVIEW

In the past century, orthodontic appliances and systems have evolved according to public demand and available technology[3]. For decades, orthodontic appliances consisted of custom fitted bands cemented on each tooth, covering nearly half of the exposed tooth surface of erupted crowns. The development of bonded adhesives introduced direct bracket bonding, eliminating altogether or limiting band placement to only posterior teeth. Elastomeric ligature ties soon all but replaced steel ligatures as a means of engaging archwires, and introduced a variety of colors for patients to select at each appointment. Plastic and ceramic brackets were developed to provide a relatively clear and esthetic alternative to metal braces[4], but also introduced greater complications with bonding and breakage, decreased treatment efficiency and increased costs to the patient and provider[7-9]. Furthermore, clear elastomeric ties used in conjunction with ceramic brackets tend to discolor between appointments, potentially reducing the esthetic qualities of the bracket.

The demand for esthetic orthodontic alternatives continued to drive the market, resulting in the development of clear plastic aligners and lingual braces. With clear plastic tray aligners

(e.g. Invisalign®), successive minor tooth movements are programmed into a series of custom fit removable trays[10]. Though they provide an esthetic and hygienic alternative to braces, they appear limited in the scope and extent of tooth movements available to the doctor[11-13]. Lingual braces, placed on the lingual surfaces of upper and lower teeth, provide the most invisible option for orthodontic treatment, but are limited in their acceptance by many practitioners due to the perceived difficulty in placing and adjusting the appliances[14, 15].

Recent attempts to decrease treatment time and number of patient visits have led to the increased acceptance of self-ligating bracket systems[16, 17]. Numerous variations of self-ligating brackets now exist, including variations in the size, shape, method of ligation or door design and incorporation of ceramic or plastic material.

Most recently, some manufacturers' aim to provide an alternative esthetic bracket has moved against the trend for "clear" or "invisible" appliances. Companies like WildSmiles™ (Omaha, NE) incorporated unique and eye-catching shapes into the base of traditional twin brackets, allowing patients to select from heart, star, soccer ball, football, or diamond-shaped braces.

Current trends for dental and orthodontic treatment planning include a paradigm shift toward dental esthetics and soft tissue planning[1]. Doctors and patients are becoming more aware not only of how function can be improved through treatment, but how the treatment will contribute to the overall facial esthetics in terms of soft tissue profile, lip protrusion, buccal corridors, smile arc etc. Esthetic concerns have increased the demand for orthodontics in both children and adults as well as the demand for more esthetic orthodontic appliances. Consequently, the number of orthodontic offices offering esthetic orthodontic options continues to increase. A 2008 survey of 808 US orthodontic practices found that 83% of orthodontists offered ceramic brackets in their offices, an increase of nearly 18% from 65.4% in 1996[18]. The same survey reported an increase of nearly 100% in the routine use of Invisalign® in orthodontic

offices from 2002 to 2008. A 2007 survey of US orthodontic residents found that 84% plan to use Invisalign® in their practices and 10.87% plan to use lingual braces. Recently, Align Technologies introduced Invisalign® Teen®, a clear tray aligner product developed and marketed specifically for the adolescent patient.

The trend in orthodontics to reduce the visibility of appliances suggests that patients are more willing to accept treatment with clear alternatives over traditional metal brackets. Some studies have sought to validate these assumptions[5, 6]. Advances in computer technology have made is easier to manipulate images to isolate key differences and eliminate confounding variables, allowing a fair comparison within the desired esthetic parameters. In recent studies, adult subjects were presented circumoral (dental) smiling images of various orthodontic appliances mounted on a model dentition[5, 6]. Subjects rated each appliance using a Visual Analog Scale (VAS) to assess appliance attractiveness and a yes/no question to assess acceptability. They found that attractiveness and acceptability varied significantly by appliance type: alternative appliances > ceramic brackets > ceramic self-ligating brackets > all stainless steel twin and self-ligating brackets. They found no statistical significance between the various brands or styles within each category. These studies showed that adult consumers value less metal show in their braces and were less willing to accept treatment with appliances they consider to be unesthetic.

Though this earlier research[5, 6] presents a baseline of esthetic values for the adult patient, by asking if the same appliances would be acceptable for use in their children they only indirectly answered how appliance esthetics applied to children by inquiring of their parents. It seems likely that children and adolescents may differ from adults in making esthetic judgments, and thus may come to different conclusions than adults. In a survey of 160 orthodontically treated and untreated 27-year old Swedish adults, 84% responded that they did or would have been willing to wear visible braces during adolescence if needed[13]. When asked if this same group would be willing to wear visible braces as an adult, 77% of previously untreated subjects responded

definitely or probably, compared to only 60% of those who had undergone previous orthodontic treatment. This suggested that children would be more willing to accept treatment with visible appliances than adults. Similarily, Zuichkovski et al found that all appliances rated less-acceptable by adults, were rated significantly higher in reference to their children[5]. Rosvall et al, however, found no difference in how adult patients rated appliance acceptability for themselves or their children[6]. These results, however, only represent an adult perspective of child and adolescent acceptability. No studies to date have directly assessed the child's perception of bracket attractiveness and acceptability.

STATEMENT OF THE PROBLEM

Though the demand for orthodontics has increased in adult patients, children continue to make up the majority of orthodontic patients in private practices. A practitioner desiring to provide esthetic appliances to his or her patient base is typically constrained by the financial need to limit inventory, appeal to patient esthetics and complement their biomechanical treatment philosophy. Understanding which appliances are preferred by the majority of patients will provide guidance in providing appliances that appeal to the greatest number of patients. Well designed studies that allow a comparison of bracket esthetics under unbiased conditions where confounding variables are eliminated are the gold standard for comparing appliance esthetics. Such studieshave been performed to evaluate adult preferences[5, 6], but understanding the esthetic desires of the entire patient base requires further investigation of the preferences of children and adolescents.

The overall objective of this research is to determine how children perceive the esthetic attractiveness and acceptability of a variety of orthodontic appliances. This study is an extension of previous research[5, 6], expanding appliances studied to include shaped brackets, colored

elastomeric ties, and discolored clear elastomeric ties on ceramic brackets. This research served to evaluate the overall preferences of children and compare the interaction of preferences at different ages and between sexes. By comparing the results of this study against those of previous researchers we can highlight differences in esthetic parameters between children and adults. This information will help practitioners recognize and meet the demands of young patients in their practices and provide a baseline of data to be used to assess future changes in patient preferences.

SPECIFIC AIMS

1. To determine if there is a difference in perceived esthetics among children regarding the following independent variables:
    a. Stainless steel brackets with clear ties
    b. Stainless steel brackets with colored ties
    c. Ceramic brackets with "new" clear ties
    d. Ceramic brackets with "aged" clear ties
    e. Self-ligating stainless steel brackets
    f. Esthetic self-ligating brackets
    g. Shaped brackets with silver ties
    h. Shaped brackets with colored ties
    i. Clear plastic aligners
2. To determine whether age differences and sex have an effect on perceived bracket attractiveness in children

NULL HYPOTHESIS

1. There are no differences in perceived esthetics/orthodontic bracket attractiveness:
    a. Between ceramic, and stainless steel brackets and plastic trays aligners

b. Between esthetic self-ligating brackets, traditional self-ligating brackets and standard twin stainless steel brackets
c. Between alternative shaped brackets and traditional stainless steel brackets
d. Between ceramic brackets with new ties and ceramic brackets with aged ties
e. Between stainless steel brackets with clear ties and stainless steel brackets with colored ties
f. Between children at various ages
g. Between male and female children

REFERENCES

1. Sarver DM, Ackerman JL. Orthodontics about face: The re-emergence of the esthetic paradigm. Am J Orthod Dentofacial Orthop. 2000;117:575-6.

2. Keim RG, Gottlieb EL, Nelson AH, Vogels DS,3rd. 2007 JCO orthodontic practice study. part 1: Trends. J Clin Orthod. 2007;41:617-26.

3. Willems G, Carels CE. Developments in fixed orthodontic appliances. Ned Tijdschr Tandheelkd. 2000;107:155-9.

4. Russell JS. Aesthetic orthodontic brackets. J Orthod. 2005;32:146-63.

5. Ziuchkovski JP, Fields HW, Johnston WM, Lindsey DT. Assessment of perceived orthodontic appliance attractiveness. Am J Orthod Dentofacial Orthop. 2008;133:S68-78.

6. Rosvall MD, Fields HW, Ziuchkovski J, Rosenstiel SF, Johnston WM. Attractiveness, acceptability, and value of orthodontic appliances. Am J Orthod Dentofacial Orthop. 2009;135:276.e1,12; discussion 276-7.

7. Redd TB, Shivapuja PK. Debonding ceramic brackets: Effects on enamel. J Clin Orthod. 1991;25:475-81.

8. Loftus BP, Artun J, Nicholls JI, Alonzo TA, Stoner JA. Evaluation of friction during sliding tooth movement in various bracket-arch wire combinations. Am J Orthod Dentofacial Orthop. 1999;116:336-45.

9. Omana HM, Moore RN, Bagby MD. Frictional properties of metal and ceramic brackets. J Clin Orthod. 1992;26:425-32.

10. Chenin DA, Trosien AH, Fong PF, Miller RA, Lee RS. Orthodontic treatment with a series of removable appliances. J Am Dent Assoc. 2003;134:1232-9.

11. Joffe L. Invisalign: Early experiences. J Orthod. 2003;30:348-52.

12. Djeu G, Shelton C, Maganzini A. Outcome assessment of invisalign and traditional orthodontic treatment compared with the american board of orthodontics objective grading system. Am J Orthod Dentofacial Orthop. 2005;128:292,8; discussion 298.

13. Meier B, Wiemer KB, Miethke RR. Invisalign--patient profiling. analysis of a prospective survey. J Orofac Orthop. 2003;64:352-8.

14. Ling PH. Lingual orthodontics: History, misconceptions and clarification. J Can Dent Assoc. 2005;71:99-102.

15. Poon KC, Taverne AA. Lingual orthodontics: A review of its history. Aust Orthod J. 1998;15:101-4.

16. Hain M, Dhopatkar A, Rock P. The effect of ligation method on friction in sliding mechanics. Am J Orthod Dentofacial Orthop. 2003;123:416-22.

17. Tecco S, Di Iorio D, Cordasco G, Verrocchi I, Festa F. An in vitro investigation of the influence of self-ligating brackets, low friction ligatures, and archwire on frictional resistance. Eur J Orthod. 2007;29:390-7.

18. Keim RG, Gottlieb EL, Nelson AH, Vogels DS,3rd. 2008 JCO study of orthodontic diagnosis and treatment procedures, part 1: Results and trends. J Clin Orthod. 2008;42:625-40.

CHAPTER 2

MATERIALS AND METHODS

This research is designed as a computer based survey, incorporating standardized digital images of orthodontic appliances to evaluate the esthetic preferences of children and adolescents. It is an extension of research projects previously performed by Ziuchkovski et al and Rosvall et al, and uses some of their previously acquired and standardized images[5, 6]. Research design and survey presentation is the same as utilized inthese previous studies to maintain uniformity and allow a more accurate comparison of results. New variables studied in this project (colored elastomeric ties, shaped brackets, and discolored clear elastomeric ties) were digitally incorporated onto existing images acquired previously in order to limit confounding variables. A summary of the initial capture and manipulation of these is outlined below. For more detail on methods of image acquisition and standardization the reader is referred to the original publications.

IMAGE CAPTURE AND STANDARDIZATION

The following outlines the capture and standardization of images as described by Rosvall et al[6].

> "A model was selected for application of orthodontic appliances and image capture on the basis of good alignment of teeth and absence of strong gender markers in the circum-oral region. Alginate impressions were obtained of the model's maxillary dentition and used for fabrication of appliance placement jigs which allowed for precise and repeatable placement of orthodontic appliances. All images were captured utilizing a

custom camera jig with a Nikon™ (Melville, NY) D100 digital camera equipped with a Nikkor™ 24-85mm macro lens and Nikon™ SB-29s Macro Speedlight flash. Camera settings were manually set, with all image adjustment features turned off, and held constant for all captured images. The color mode was set to Adobe RGB and the image quality to RAW (NEF files). A GretagMacbeth® (X-Rite, Grand Rapids, MI) Mini ColorChecker® was fastened to the jig to allow for color calibration. While the images were captured, all lighting was turned off with the exception of a 6500K (Ideal-Luume®) lamp placed in a fixed location.

All appliances were bonded to the model's maxillary dentition (second premolar to second premolar) using 3M Unitek's (St. Paul, MN) Transbond XT™ light cure adhesive and Transbond™ Plus self etching primer. The wire utilized was GAC International, Inc.'s (Bohemia, NY) 14mil Sentaloy® NiTi, ligated with 3M Unitek's AlastiK™ clear ligatures. An Essix® (Raintree Essix, Metairie, LA) appliance (clear tray) was imaged to simulate clear tray alignment systems such as Invisalign®(Align Technology Inc., Santa Clara, CA). Extraoral images of the peri-oral region were also captured with the model smiling for later use as a smile layer.

All images were standardized for color and format with Adobe® (San Jose, CA) Photoshop® 7.0 and the Pictocolor InCamera® (Burnsville, MN) (version 4.0.1) plug-in software. With the InCamera® software, a custom ICC color profile was created and applied to each image using the GretagMacbeth Mini Color Checker® color patches as standard reference. This process standardized all of the images, with respect to color, to the standard color reference patches. To limit confounding variables, a standard smile layer was created and placed over each of the intra-oral appliance images to create images with variable orthodontic appliances and constant soft tissue features. The position of the intra-oral image with reference to the smile layer was standardized by best

fitting the images to vertical and horizontal reference lines. Constant position and size of the intraoral images were verified by toggling between all of the intraoral layers within the Photoshop® program. Consistent position of arch wires was verified with this same technique to assure similar smile-arch characteristics."

Examples of several images acquired by this method are displayed in Figure 3.1.

Shaped Brackets

Shaped brackets were supplied by WildSmiles™ (Omaha, NE) and incorporated onto existing images. WildSmiles™ star and heart shaped brackets were selected to represent bracket styles most appealing to male and female subjects. Brackets were mounted on a typodont model from maxillary canine to canine in proper mesial-distal and incisal-gingival position. A 14mil Sentaloy® NiTi (GAC International, Inc.) wire was engaged with clear elastomeric ties. Images of the brackets were captured using a Nikon™ D60 digital Camera with standard flash and Nikkor™ 18-55mm lens. Images were taken at several vertical positions and an image was selected that best approximated the smile arc represented on existing bracket images. Using Adobe® Photoshop® Elements 7.0, WildSmiles™ brackets and ligature ties were individually cut and layered over an existing image at corresponding maxillary canine to canine brackets. Bracket brightness, contrast, hue and saturation were adjusted to match adjacent brackets. Examples of WildSmiles® images are displayed in Figure 3.2.

Colored Elastomeric Ties

Clear elastomeric ties on existing survey images were digitally enhanced to simulate colored elastomeric ties. Individual ties were traced and layered in Adobe® Photoshop® 7.0 on MicroArch® and WildSmiles™ bracket images. The hue, saturation and lightness of elastomeric ties were adjusted to create accurate representations of red, dark red, green, orange, blue, light blue, pink, purple, violet and gray ties. These colors were used to show a sample of possible

color options that patients could choose at appointments. Care was taken to record the level and degree of color enhancement to standardize colors between bracket images. Examples of colored elastomeric ties are displayed in Figure 3.3.

Discolored Clear Elastomeric Ties

Similar techniques were used to simulate the discoloration of clear elastomeric ties that typically occurs between appointments. Prior to image enhancement, digital photos were taken of several patients with ceramic brackets and clear elastomeric ties 4-6 weeks following ligature tie placement. These images were used to reference the degree of discoloration typically seen at adjustment appointments. Using Adobe Photoshop, clear elastomeric ties on Mystique brackets were outlined and layered on an existing survey image, then discolored (yellowed and darkened) according to actual patient images. An example of these brackets is displayed in figure 3.4.

Bracket Selection

The following bracket styles and brands were tested:

1. Stainless steel – Microarch (GAC International, Bohemia, NY)
2. Stainless steel self-ligating - In-Ovation R (GAC International, Bohemia, NY) and Damon 3 (Ormco, Orange, CA)
3. Ceramic self-ligating - In-Ovation C (GAC International, Bohemia, NY)
4. Ceramic - Mystique (GAC International, Bohemia, NY)
5. Shaped brackets – WildSmiles (Omaha, NE)
6. Plastic tray aligners – Essix (Raintree Essix, Metairie, LA)

Previous research[5, 6] showed no significant difference between how adult subjects rated the three ceramic brackets: Mystique® (GAC International), Ice (Ormco), and Clarity™ (3M Unitek). Because Mystique® had the highest average VAS score in previous research[6], it was selected to represent ceramic brackets in this survey. There was also no significant difference in

previous studies[5, 6] between the control (representing lingual braces) and the Essix® (representing Invisalign®). Because it could be confusing for children to rate an orthodontic appliance that they could not see, we eliminated the lingual braces image from this survey. Table 3.1 details the appliances and ligature tie combinations used in this study.

SURVEY PREPARATION AND ADMINISTRATION

Acquired and standardized images were incorporated into a computer-based survey and administered to children and adolescents 9-17 years old. The survey was designed and prepared by James Christensen PhD using MATLAB R2008a (The Mathworks, Inc., Natick, MA). A customized mouse-operated graphical interface was developed that combined data collection and survey administration. Images were displayed on an HP Pavillion dv6000 (Palo Alto, CA) laptop with 17" monitor at a life-size ratio to allow a realistic assessment of bracket esthetics.

The study design and research protocol involving human subjects was approved by the Institutional Review Board (IRB). Subjects were recruited at the orthodontic screening clinic and Pediatric Dental Clinic in the College of Dentistry at The Ohio State University. Eligibility to participate in the survey included any willing child 9-17 years old who had never undergone orthodontic treatment with brackets or aligners. All children screened for orthodontic treatment who fell within the target age groups were introduced to the research project and invited to participate in the survey following their orthodontic screening. Family members in the same age range and present at the screening visit who met the research criteria were also invited to participate in the study. Furthermore, at times available to research investigators, all parents of patients checking in at the Pediatric Dental Clinic were given an information sheet introducing the survey. The information sheet explained the objectives, eligibility requirements and compensation of the research, and invited parents to inform the Pediatric front desk personnel if

their child was interested in participating. Interested patients and parents were directed to meet with the research investigators who further introduced the survey to the child and parent in an orthodontic screening room and obtained consent and assent. A scripted introduction briefly describing the purpose of the study, subject expectations and compensations was read to each patient and family member that fell within the target age. Specifically, the participants were told that participation in the project is voluntary and anonymous, that no discomfort or risk to the participant is expected, that the participant can choose not to participate without penalty, and that they can withdraw from the study at any time without penalty. Participants were informed that no written consent is required because the study meets the conditions for its waiver, however verbal assent from children and verbal consent from parents present must be obtained. A log was kept by the researcher to record the number of subjects participating and their ages, however no personally identifiable information was recorded within the survey or by the researcher. Subjects were given a $10 gift card for participating in the study.

All surveys were completed on the researcher's laptop computer in the consultation rooms of the orthodontic screening clinic. Survey design included a scripted introduction, demographic information, instructions, and image rating pages. Subjects navigated through the survey by clicking "next", and any question, other than optional demographic information, that was not answered completely prompted the message: "Please answer all questions before continuing", to which subjects were required to respond before advancing to the next question.

The scripted introduction informed subjects that they would be rating 12 images of different types of braces, that there were no right or wrong answers, and that the survey would take 10-15 minutes to complete. It was reiterated that all answers would be kept confidential and that the subject was free to quit the study at any time. Subjects agreed to participate in the study by clicking to the next screen. Demographic pages consisted of listed menu options for the following fields: age, gender, and ethnicity. Age could be selected for each whole year 9 years

old to 17 years old. The categories for gender were listed as male/boy and female/girl. The categories for ethnicity were listed in order as: (1) African American/Black, (2) Asian/Pacific Islander, (3) Caucasian/White, (4)Hispanic/Latin American, (5) Middle Eastern, (6) Native American, and (7) Other.

Following demographic information, a series of tutorial screens instructed subjects on how to complete the survey and gave examples of orthodontic appliances to be rated. Subjects were instructed on how to use the visual analog scale on a sample survey question and could practice using the scale by clicking or dragging the VAS marker. After the subject had familiarized themselves with the VAS question, an example of red elastomeric ties was shown on a full smile image of MicroArch® brackets, displayed over a series of nine various colored elastomeric ties on single brackets. Subjects were instructed that these images represented the ability to select various colored ties at each orthodontic visit. Subjects were then shown an image of a clear tray aligner and instructed that "some types of braces don't have anything glued to the teeth, but are clear plastic trays that fit tightly around the teeth." At the conclusion of the instructional pages, subjects were presented a grid of all 12 images, and instructed to take a minute to look at all images before starting the survey. By doing so, subject could familiarize themselves with all appliances before rating the first image displayed.

The image rating pages consisted of a visual analog scale (VAS) question and a yes/no question. Images to be rated were displayed in the center of the screen, directly above the question "How good do you think these braces look?" Subjects answered by means of the visual analog scale, a horizontal bar anchored by the text "Really Good" on the right, and "Really Bad" on the left. A thin gray marker in the middle of the bar could be dragged to the desired spot along the scale, or the subject could simply click anywhere along the bar to move the marker to that point. Subjects were then asked the acceptability question "If you were going to have braces, would you be willing to wear these?" VAS marker location and yes/no answers could be

changed at any time before advancing to the next screen, at which time all responses were recorded. Subjects could not navigate back to previous pages after answers had been recorded. Each orthodontic appliance image was displayed in random order. After each image had been displayed and rated once, all images were randomly displayed again and the same questions asked to evaluate intra-rater reliability.

The final survey page displayed a grid of all 12 appliance images. Subjects were asked "If you were going to have braces, which appliance style would you prefer most? Click on the picture of your favorite style, then click on your second favorite, 3rd, 4th, and 5th." As subjects clicked on the images, the image became shaded over with a number "1", number "2", number "3", etc. Clicking on any image a second time would unselect it from the ranking and readjust any subsequently selected images. A "Reset" button at the bottom of the screen also allowed subjects to reset all images selected. Subjects could complete the survey only after all five images were selected.

SAMPLE

The sample size was based on a power analysis using results from previous studies[5, 6]. The results of this analysis showed that a sample of 45 subjects in each age group (9-11 years, 12-14 years, 15-17 years) was needed to detect statistical significance with a power of 0.8 and an alpha of 0.05. This allowed pair-wise comparisons between each of the three groups studied and potentially detect differences as small 12% on the VAS scale.

141 subjects attempted to take the survey. One subject chose not to complete the survey after starting and subsequent responses were not recorded by the survey program. Another subject claimed to have a difficult time seeing the screen, and required assistance from his older sister, who had taken the survey previously, to answer the survey questions. As he was unable to

complete the survey on his own, responses from his survey were not included in statistical analysis or demographic information. The remaining subjects (n=139) are detailed by their demographic groupings in Table 3.2.

STATISTICAL ANALYSIS

Each image used in the survey was rated twice to assess intra-rater reliability. All VAS and acceptability values used for statistical analysis are averages of both ratings. For acceptability, recorded as either 0 or 1, this produced a value of 0.5 if the subject rated the appliance as acceptable one time, and unacceptable another. Any such responses represented a borderline acceptable bracket.

In the survey, two bracket shapes were used to represent WildSmiles™ braces. The intent of using various WildSmiles™ brackets in the study was not to determine a ranking or preference between shaped bracket styles, but to determine how shaped brackets in general rated against other common appliances. Therefore, for each individual subject, the WildSmiles™ bracket (heart or star) rated highest according to VAS was used to represent the rater's preference for shaped brackets. The other bracket was eliminated from statistical analysis comparing WildSmiles™ to other appliances. This was done for both colored and clear elastomeric ties.

The final rating page or rank list, where subjects were instructed to rank their five favorite appliances, was used as a second measure to validate attractiveness and acceptability results. Because the subject was selecting between 12 appliance options, a 12 point scale was used to objectively evaluate overall brackets preferences. Appliances selected first were assigned 12 points; those selected second 11 points; those selected third 10 points, etc. Any appliance that was not selected in the subject's top five was assigned zero points. Point totals for each bracket were averaged to find the overall preference of brackets in each age group. In order to compare

the effect of colored elastomeric ties on stainless steel brackets, ratings from each colored bracket option (MicroArch®, WildSmiles™ stars, and WildSmiles™ hearts) were combined in each age group to compare against the non-color bracket counterpart.

Intra-rater reliability for the attractiveness study was evaluated by the Strout Fleiss Intraclass Correlation Coefficient. Reliability of Yes/No responses for acceptability was assessed by kappa statistic. VAS ratings were analyzed using a factorial analysis of variance (ANOVA) with repeated measures. Mean scores of VAS ratings were adjusted using the least squared means method. Because each image was rated more than once, acceptability values were converted to relative frequency of response, and statistically analyzed in a manner the same as VAS ratings. Bonferroni correction was applied when multiple comparisons were performed (overall alpha<0.05). Statistical analyses were calculated with SAS® (version 9.2).

REFERENCES

1. Ziuchkovski JP, Fields HW, Johnston WM, Lindsey DT. Assessment of perceived orthodontic appliance attractiveness. Am J Orthod Dentofacial Orthop. 2008;133:S68-78.

2. Rosvall MD, Fields HW, Ziuchkovski J, Rosenstiel SF, Johnston WM. Attractiveness, acceptability, and value of orthodontic appliances. Am J Orthod Dentofacial Orthop. 2009;135:276.e1,12; discussion 276-7.

CHAPTER 3

MANUSCRIPT:

Orthodontic Appliance Preferences of Children and Adolescents

ABSTRACT

Although attractiveness and acceptability of orthodontic appliances have been rated by adults for themselves and adolescents, children and adolescents have not provided any substantial data. **Objective:** To evaluate children and adolescent preferences and acceptability of orthodontic appliances. **Methods:** Images of orthodontic appliances previously captured and standardized for the research of Zuichkovski et al and Rosvall et al were selected and incorporated into a computer-based survey. Additional images of shaped brackets and colored elastomeric ties, as well as discolored clear elastomeric ties were captured and incorporated onto existing survey images with Adobe® Photoshop®. The survey displayed twelve orthodontic appliance variations to 135 children (n=45 of each 9-11 years, 12-14 years, 15-17 years). Subjects rated each image for attractiveness on a visual analog scale (VAS) and acceptability (yes/no). All images were displayed and rated twice to assess rater reliability. **Results:** Overall reliability for attractiveness rating was r=0.74 and k=0.66 for acceptability. There were significant differences in bracket attractiveness and acceptability in each age group. The highest rated appliances were clear aligners, twin brackets with colored ties, and shaped brackets with and without colored ties. Colored elastomeric ties improved attractiveness significantly over brackets without colored ties for children 12-14 years. There was a tendency for older subjects to rate clear orthodontic appliances higher than younger subjects. Ceramic brackets with discolored ties tended to be rated lower than ceramic brackets with new ties, and scored lowest in acceptability and attractiveness

in all age groups. Female subjects rated shaped brackets significantly higher than male subjects. **Conclusions:** The results of this research demonstrate that children's preference for orthodontic appliances differs by age and gender. Child and adolescent preferences differ from adult preferences.

INTRODUCTION

Traditionally, the options for bracket style or appliance design were considerably limited for both the patient and provider. Recently, the orthodontic market has experienced phenomenal growth in the development and production of orthodontic appliances that are designed to appeal to the patient consumer. A shifting paradigm toward dental esthetics[1], increased demand for orthodontic treatment[2], consumer driven desire for esthetic treatment alternatives, and a competitive orthodontic industry and profession have all contributed to the development and production of alternative orthodontic appliances and new bracket styles[3, 4]. Orthodontic patients and practitioners are now presented with a variety of treatment options previously unavailable.

Orthodontic appliances have evolved according to public demand and available technology, with the underlying goal, in large part, to reduce visibility of the appliances [3]. With the development of successful direct bonding techniques, the use of custom fitted bands was replaced by bondable brackets. Plastic and ceramic brackets were developed to provide a relatively clear and esthetic alternative to metal braces[4], but also introduced greater complications with bonding and breakage, decreased treatment efficiency and increased costs to the patient and provider[7-9]. Clear plastic tray aligners (e.g. Invisalign®) and lingual braces were developed to provide even more invisible options for patients, but were fraught with even more clinical obstacles and treatment limitations[11-15].

Some advances in appliance design, however, have moved against the trend for clear or invisible appliances. The development of elastomeric ligature ties for the most part replaced steel

ligature ties as a means of engaging archwires, and introduced a variety of colors for patients to select. Companies like WildSmiles™ (Omaha, NE) incorporated unique and eye-catching shapes into the base of traditional twin brackets, allowing patients to select from heart, star, soccer ball, football, or diamond-shaped braces.

Just as each orthodontic appliance is unique in its esthetic qualities, each also has biomechanical benefits and potential limitations. For a practitioner providing bracket options for patients, selecting which bracket to offer becomes a function of both esthetics and functionality--what will be esthetically acceptable to the patient and clinically efficient for the doctor.

Few studies have investigated the patient perception of appliance esthetics. Ziuchkovski et al evaluated the attractiveness and acceptability of traditional, ceramic, self-ligating, and lingual braces, as well as clear aligners in adult subjects and for their children[5]. Rosvall et al evaluated an expanded set of bracket options and included an assessment of the value of esthetic appliances to consumers[6]. Both studies found that attractiveness and acceptability varied significantly by appliance type: alternative appliances (lingual and clear aligners)> ceramic brackets > ceramic self-ligating brackets > all stainless steel twin and self-ligating brackets. They found no statistical significance between the various brands or styles within each category. These studies showed that adult consumers value less metal show in their braces and were less willing to accept treatment with appliances they consider to be unesthetic.

Though this earlier research[5, 6] presents a baseline of esthetic values for the adult patient, it only indirectly answered how appliance esthetics applies to children. When adult subjects were asked if the appliances would be acceptable for use in their child's orthodontic treatment, Ziuchkovski et al[14] found that all appliances that were rated less-acceptable by adults, were rated significantly higher in reference to their children. Rosvall, however, found no difference in how adult patients rated appliance acceptability for themselves or their children[5]. In a survey of 160 orthodontically treated and untreated 27-year old Swedish adults, 84% responded that they did or

would have been willing to wear visible braces during adolescence if needed[13]. When asked if this same group would be willing to wear visible braces as an adult, 77% of previously untreated subjects responded definitely or probably, compared to only 60% of those who had undergone previous orthodontic treatment. This suggested that children would be more willing to accept treatment with visible appliances than adults. At this point, no one has asked children and adolescents what they favor relative to orthodontic appliances and their esthetics. Such studies have been performed to evaluate adult preferences[5, 6], but understanding the esthetic desires of the entire patient base requires further investigation of the preferences of children and adolescents.

The purpose of this study was to determine how children perceive the esthetic attractiveness and acceptability of a variety of orthodontic appliances. This research evaluated the overall preferences of children and compared the interaction of preferences at different ages and between sexes. This information will help practitioners recognize and meet the demands of young patients in their practices and provide a baseline of data to be used to assess future changes in patient preferences.

MATTERIALS AND METHODS

This research was designed as a computer-based survey, incorporating standardized digital images of orthodontic appliances to evaluate the esthetic preferences of children and adolescents. It is an extension of research projects previously performed by Ziuchkovski et al and Rosvall et al, and uses some of their previously acquired and standardized images[5, 6]. Research design and survey presentation is the same as utilized in these previous studies to maintain uniformity and allow a more accurate comparison of results. New variables studied in this project (colored elastomeric ties, shaped brackets, and discolored clear elastomeric ties) were digitally incorporated onto existing images acquired previously in order to limit confounding variables. A summary of the initial capture and manipulation of these is outlined below. For more detail on

methods of image acquisition and standardization the reader is referred to the original publications[5, 6].

Image Capture and Standardization

A model was selected for placement and imaging of orthodontic appliances on the basis of good alignment of teeth and the absence of strong gender markers in the circum-oral region. Fabrication of a custom jig specific to the model's dentition allowed for precise and reproducible placement of various bracket systems. Brackets were bonded from maxillary second molar to second molar and a 14mil Sentaloy® NiTi (GAC International, Inc., Bohemia, NY) was engaged in with AlastiK™ clear ligatures (3M Unitek, St. Paul, MN). An Essix® (Raintree Essix, Metairie, LA) appliance (clear tray) was fabricated and imaged to simulate clear tray alignment systems such as Invisalign® (Align Technology Inc., Santa Clara, CA).

Images were captured with a Nikon™ (Melville, NY) D100 digital camera equipped with a Nikkor™ 24-85mm macro lens and Nikon™ SB-29s Macro Speedlight flash. Camera settings were manually set and all in-camera image enhancement features turned off. A custom jig was used for image acquisition to standardize the camera distance and angle. Lighting conditions were constant for all images acquired and a GretagMacbeth®(X-Rite, Grand Rapids, MI) Mini ColorChecker™ was fastened to the jig to allow for standardization of images to the standard color reference patches.

Image incorporation and standardization was performed with Adobe® (San Jose, CA) Photoshop® 7.0 and the Pictocolor® inCamera™(Burnsville, MN) version 4.0.1 plug-in software. To limit confounding variables, a standard peri-oral smiling image of the model was captured and layered over intra-oral appliance images. Appliance image position in reference to the smile layer was standardized by means of vertical and horizontal reference lines and verified by toggling between intra-oral layers within Photoshop®. Examples of several images acquired by this method are displayed in Figure 3.1.

Shaped Brackets

Shaped brackets were supplied by WildSmiles™ (Omaha, NE) and incorporated onto existing images. WildSmiles™ star and heart shaped brackets were selected to represent bracket styles most appealing to male and female subjects. Brackets were mounted on a typodont model from maxillary canine to canine in proper mesial-distal and incisal-gingival position. A 14mil Sentaloy® NiTi (GAC International, Inc.) wire was engaged with clear elastomeric ties. Images of the brackets were captured using a Nikon™ D60 digital Camera with standard flash and Nikkor™ 18-55mm lens. Using Adobe® Photoshop® Elements 7.0, WildSmiles™ brackets and ligature ties were individually cut and layered over an existing image at corresponding maxillary canine to canine brackets. Bracket brightness, contrast, hue and saturation were adjusted to match adjacent brackets. Examples of WildSmiles™ images are displayed in Figure 3.2.

Colored Elastomeric Ties

Clear elastomeric ties on existing survey images were digitally enhanced to simulate colored elastomeric ties. Individual ties were traced and layered in Adobe® Photoshop® 7.0 on MicroArch® and WildSmiles™ bracket images. The hue, saturation and lightness of elastomeric ties were adjusted to create accurate representations of red, dark red, green, orange, blue, light blue, pink, purple, violet and gray ties. These colors were used to show a sample of possible color options that patients could choose at appointments. Care was taken to record the level and degree of color enhancement to standardize colors between bracket images. Examples of colored elastomeric ties are displayed in Figure 3.3.

Discolored Clear Elastomeric Ties

Similar techniques were used to simulate the discoloration of clear elastomeric ties that typically occurs between appointments. Prior to image enhancement, digital photos were taken of several patients with ceramic brackets and clear elastomeric ties after 4-6 weeks of placement and

used to reference the degree of discoloration typically seen at adjustment appointments. Using Adobe® Photoshop®, clear elastomeric ties on Mystique® brackets were then discolored (yellowed and darkened) according to actual patient images. An example of these brackets is displayed in figure 3.4.

Bracket Selection

Previous research[5, 6] showed no significant difference between how adult subjects rated the three ceramic brackets: Mystique® (GAC International), Ice (Ormco), and Clarity™ (3M Unitek). Because Mystique® had the highest average VAS score in previous research[6], it was selected to represent ceramic brackets in this survey. There was also no significant difference in previous studies[5, 6] between the control (representing lingual braces) and the Essix® (representing Invisalign®). Because it could be confusing for children to rate an orthodontic appliance that they could not see, we eliminated the lingual braces image from this survey. Table 3.1 details the appliances and ligature tie combinations used in this study.

SURVEY PREPARATION AND ADMINISTRATION

Acquired and standardized images were incorporated into a computer-based survey and administered to children and adolescents 9-17 years old. The survey was designed and prepared using a numerical computing environment and programming language software, MATLAB R2008a (The Mathworks, Inc., Natick, MA). A customized mouse-operated graphical interface was developed that combined data collection and survey administration. Images were displayed on an HP Pavillion dv6000 (Palo Alto, CA) laptop with 17" monitor at a life-size ratio to allow a realistic assessment of bracket esthetics.

The study was approved by the Institutional Review Board (IRB). Subjects were recruited in the college clinics. Eligibility to participate in the survey included any willing child

9-17 years old who had never undergone orthodontic treatment with brackets or aligners. All surveys were completed on a laptop computer in the consultation rooms of the orthodontic clinic. The computer survey included an introduction, demographic information, instructions, and image rating screens. Subjects navigated through the survey by clicking "next", and were prevented from proceeding if all questions were not completely answered.

A series of tutorial screens instructed subjects on how to complete the survey and gave examples of orthodontic appliances to be rated. Subjects were instructed on how to use the visual analog scale (VAS) on a sample survey question, and could practice using the scale by clicking or dragging the VAS marker. As an example of colored elastomeric ties, subjects were shown a full smiling image of MicroArch® brackets with red ties, displayed over a series of nine various colored elastomeric ties on single brackets. Subjects were told that these images represented the ability to select various colored ties at each orthodontic visit. Subjects were also briefly introduced to clear tray aligners, and shown an image of an Essix® appliance. At the conclusion of the instructional pages, subjects were presented a grid of all 12 appliance images and instructed to take a minute to look at all images before starting the survey. By doing so, subject could familiarize themselves with all appliances before rating the first image displayed.

The image rating pages consisted of a visual analog scale (VAS) question and a yes/no acceptability question. Subjects were presented the image to be rated and were asked "How good do you think these braces look?" Attractiveness was gauged by means of the visual analog scale, a horizontal bar anchored by the text "Really Good" on one side and "Really Bad" on the other. A thin gray marker in the middle of the bar could be dragged to the desired spot along the scale, or the subject could simply click anywhere along the bar to move the marker to that point. Subjects were then asked the acceptability question "If you were going to have braces, would you be willing to wear these?" Each orthodontic appliance image was displayed in random order. After each image had been displayed and rated once, all images were randomly displayed again and the same questions asked to evaluate intra-rater reliability.

The final survey page displayed a grid of all 12 appliance images. Subjects were asked "If you were going to have braces, which appliance style would you prefer most? Click on the picture of your favorite style, then click on your second favorite, 3rd, 4th, and 5th." While seeing all appliance options, subjects could then rank their five favorite brackets.

SAMPLE

The sample size was based on a power analysis using results from previous studies[5, 6]. The results of this analysis showed that a sample of 45 subjects in each age group (9-11 years, 12-14 years, 15-17 years) was needed to detect statistical significance with a power of 0.8 and an alpha of 0.05. This allowed pair-wise comparisons between each of the three groups studied and potentially detect differences as small 12% on the VAS scale.

141 subjects attempted to take the survey. One subject chose not to complete the survey after starting and another was unable to complete the survey without help from a family member. The remaining subjects (n=139) are detailed by their demographic groupings in Table 3.2.

STATISTICAL ANALYSIS

Each image used in the survey was rated twice to assess intra-rater reliability. All VAS and acceptability values used for statistical analysis are averages of both ratings. For acceptability, recorded as either 0 or 1, this produced a value of 0.5 if the subject rated the appliance as acceptable one time, and unacceptable another. Any such responses represented a borderline acceptable bracket.

In the survey, two bracket shapes were used to represent WildSmiles™ braces. The intent of using various WildSmiles™ brackets in the study was not to determine a ranking or preference between shaped bracket styles, but to determine how shaped brackets in general rated against other common appliances. Therefore, for each individual subject, the WildSmiles™

bracket (heart or star) rated highest according to VAS was used to represent the rater's preference for shaped brackets. The other bracket was eliminated from statistical analysis comparing WildSmiles™ to other appliances. This was done for both colored and clear elastomeric ties.

The final rating page or rank list, where subjects were instructed to rank their five favorite appliances, was used as a second measure to validate attractiveness and acceptability results. Because the subject was selecting between 12 appliance options, a 12 point scale was used to objectively evaluate overall brackets preferences. Appliances selected first were assigned 12 points; those selected second 11 points; those selected third 10 points, etc. Any appliance that was not selected in the subject's top five was assigned zero points. Point totals for each bracket were averaged to find the overall preference of brackets in each age group. In order to compare the effect of colored elastomeric ties on stainless steel brackets, ratings from each colored bracket option (MicroArch®, WildSmiles™ stars, and WildSmiles™ hearts) were combined in each age group to compare against the non-color bracket counterpart.

Intra-rater reliability for the attractiveness study was evaluated by the Strout Fleiss Intraclass Correlation Coefficient. Reliability of Yes/No responses for acceptability was assessed by kappa statistic. VAS ratings were analyzed using a factorial analysis of variance (ANOVA) with repeated measures. Mean scores of VAS ratings were adjusted using the least squared means method. Because each image was rated more than once, acceptability values were converted to relative frequency of response, and statistically analyzed in a manner the same as VAS ratings. Bonferroni correction was applied when multiple comparisons were performed (overall alpha<0.05). Statistical analyses were calculated with SAS® (version 9.2).

RESULTS

Results for appliance attractiveness and acceptability are presented in Figures 3.5-3.9. Higher VAS scores (scored 0-100) and higher acceptability scores (scored 0-1) indicate greater

appliance attractiveness and acceptability. Significant interactions were found between age group by bracket and sex by bracket.

RELIABILITY

Each image was rated twice for attractiveness and acceptability to assess intra-rater reliability. Overall reliability for attractiveness rating was r=0.74 and k=0.66 for acceptability.

ATTRACTIVENESS

Group 1 (Ages 9-11)

The least squared mean VAS scores for each appliance rated by Group 1 are displayed in Figure 3.5-A. The highest rated and statistically similar appliances were MicroArch® with colored ties, WildSmiles™ with colored ties, Invisalign®, WildSmiles™, and MicroArch®. MicroArch® with colored ties, WildSmiles™ with colored ties and clear aligners were found to be statistically more attractive than all complete or partially ceramic brackets.

Group 2 (Ages 12-14)

The least squared mean VAS scores for each appliance rated by Group 2 are displayed in Figure 3.5-B. The highest rated and statistically similar appliances were the same as those in group 1, MicroArch® with colored ties, Invisalign®, WildSmiles™ with colored ties, WildSmiles™, and MicroArch®. Microarch® with colored ties and Invisalign® were rated significantly more attractive than all ceramic and hybrid brackets.

Group 3 (Ages 15-17)

The least squared mean VAS scores for each appliance rated by Group 3 are displayed in Figure 3.5-C. Clear tray aligners were rated significantly more attractive than all other appliances

rated. The order of preference for the remaining appliances was different from previous age groups, however differences were not found to be statistically significant.

Sex

The pooled attractiveness results for all male and female subjects are displayed in Figure 3.7. Two comparisons were found to be statistically significant. Female subjects rated the attractiveness of WildSmiles™ brackets significantly higher than male subjects, while male subjects rated the attractiveness of Mystique brackets with discolored ties higher significantly than females.

Colored Elastomeric Ties

Pooled VAS averages for brackets displayed with colored elastomeric ties versus clear elastomeric ties are displayed in Figure 3.8. With each age group, colored elastomeric ties rated higher than their non-colored counterpart, however this difference was only found to be statistically significant in the second age group.

ACCEPTABILITY

Acceptability rates for each appliance by age group and sex are presented in Figure 3.5. In the youngest age group, MicroArch® brackets with colored ties were rated most acceptable at 92%, significantly higher than all ceramic and hybrid appliances. MicroArch® brackets with colored ties were also rated highest in the second age group at 89%, significantly higher than all ceramic, hybrid and self-ligating appliances. In the oldest age group, clear tray aligners were rated most acceptable at 91%, significantly higher than all ceramic, hybrid, self-ligating and shaped brackets. Comparison between sexes revealed higher acceptability of shaped brackets by female subjects (see Figure 3.7).

RANK LIST

Pooled averages for appliances ranked 1-5 are displayed in figure 3.9. On average, appliance preferences scored according to the ranking system matched the VAS results from the attractiveness study in each age group.

DISCUSSION

Comparisons to Adult Subjects

Previous research[5, 6] looking at similar variables in adult subjects reported the following hierarchy of appliance preferences: alternative appliances (clear aligners and lingual brackets) > ceramic appliances > ceramic self-ligating > all hybrid and stainless steel appliances. They concluded that patients prefer appliances with less metal show. This study, however, shows substantial differences in how children's and adolescents' preferences for orthodontic appliances differ from each other at different age points and from adults in general. Though this study looked at the effect of additional variables not previously studied in the adult samples, even the variables that were the same in each study showed marked differences. For example, GAC MicroArch®, which was rated significantly lower than all ceramic appliances in the research of Zuichkovski et al, rated significantly higher than ceramic brackets in the youngest age group in this study and showed a similar trend in the second age group. With the exception of clear tray aligners, in each age group, three of the top four rated appliances were all-metal brackets. Consequently, ceramic and hybrid brackets comprised the bottom four appliance preferences in the two younger age groups. These data makes it apparent that reducing metal show in appliances is not the driving factor for esthetics among the majority of children and adolescents.

Age Groups

Differences in appliance preference were also apparent between age groups. Though differences in individual bracket scores between age groups were not statistically significant, the following trends were clear: Older subjects have a higher preference for clear appliances than younger subjects. For the youngest two age groups, all ceramic and hybrid brackets were rated significantly lower than the highest rated bracket, MicroArch® with colored ties. Attractiveness scores for ceramic and hybrid brackets appliances increased in the oldest age group, and no longer showed statistical difference from standard twin brackets. Though rated relatively high in the first two age groups, clear aligners are not rated significantly higher than other top brackets choices. However in the oldest age group, clear aligners are preferred significantly over all other brackets. When looking at each appliance individually, in all appliances but one, metal bracket ratings decrease as age group increases while ceramic and plastic appliance ratings increase as age group increases. The exception to this rule is Mystique® bracket with discolored ties which was rated consistently lowest in all age groups. These trends show the general evolution of preferences for the maturing adolescent and begin to resemble the findings of previous adult-based studies.

Attractiveness vs. Acceptability

Acceptability scores generally mimic the VAS rankings in each age group, with some notable exceptions. Traditional twin brackets (MicroArch®) without colored elastomeric ties ranked fourth or fifth in attractiveness when ranking against all other appliances in each age group. However, when looking at acceptability, these same brackets were rated second most acceptable among the first two age groups and third most acceptable in the third age group. This suggests that though the bracket may not be considered particularly esthetic, it is generally accepted by the majority of patients. Conversely, shaped brackets (WildSmiles™), which

maintain high attractiveness among all age groups, were rated lower in regards to acceptability. This suggests that although many subjects found them to be very esthetic, some would not be willing to wear them as part of their treatment.

Elastomeric Ties

The ability to select colored elastomeric ties has a significant effect upon the attractiveness of metal brackets. This preference for colored ties was observed in each age group with each colored/non-colored bracket pairs. When all three colored brackets options were combined in each age group, this preference for colored ties showed a significant difference in the second age group and neared significance in the first. Since colored ties were not rated in previous studies, no comparison can be made with the preference for colored ties in adult subjects.

Discolored clear elastomeric ties were included in this study to determine if the discoloring effect of clear ties would significantly decrease the attractiveness and acceptability of ceramic brackets over self-ligating ceramic brackets and other appliances. Though not statistically significant, brackets with discolored ties were rated consistently lower than ceramic brackets with new ties, and rated lowest of all appliances in each age group.

Rank List

The rank list at the end of the survey asked subjects to rank their five favorite appliances from all appliances displayed. Presumably, this second method of evaluating appliances could serve to validate the attractiveness and acceptability results of the study. As these rankings were pooled and objectively score, the cumulative appliance preferences based on subject rankings validated and supported the rankings obtained from the VAS results for each age group. Some individual discrepancies were noted, however, when each subject's highest ranked appliance was compared against the appliance they rated highest according to VAS. In total, 70% of subjects

selected as their number one preference the same appliance type that they rated highest in attractiveness. Interestingly, in the first two age groups the appliance selected most frequently as the subject's number one choice was some variation of WildSmiles™ brackets at 44%. The most frequently selected number one appliance in the oldest age group was clear tray aligners at 53%.

Clinical Application

The findings of this study have direct clinical implications for the practicing orthodontist. Orthodontists must select between available appliances to provide brackets that are acceptable to patients and work in harmony with their biomechanical philosophy. As children and adolescents continue to make up the vast majority of orthodontic patients, understanding which appliances are acceptable to them will help practitioners meet patients' needs. It may be reassuring to practitioners that standard stainless steel twin brackets with colored ties, typically the least expensive bracket option and most frequently employed by orthodontists[18], was rated highest in attractiveness and acceptability among children ages 9-14, and second highest among children ages 15-17. By providing these brackets, doctors can cater to the desires of over 85% of their patients.

Children and adolescents also showed a high preference for clear tray aligners. For both attractiveness and acceptability, clear aligners ranked very high in the younger age groups, and highest in the oldest age group. However, despite the overall high rating for these appliances, their practical use is somewhat limited in children and adolescents. Since its inception in 1999, Invisalign® has typically been reserved for comprehensive adult dentition cases. In recent years, however, Align Technology, Inc. has attempted to tap into this apparent demand among non-adult patients with the release of Invisalign Teen™. Though Invisalign Teen™ can provide a valid appliance option for some adolescent patients, the majority of children, especially those in mixed dentition, may not be suitable for treatment with this technology.

Another recent movement in orthodontics has been the rapid increase in the number of doctors employing self-ligating bracket systems. The use of self-ligating brackets in orthodontic offices has risen from 9.8% in 2002 to 38.2% in 2008[18]. Biomechanically and clinically, many advantages over traditional brackets have been claimed, including more rapid and efficient tooth movement[19], reduced friction[20], reduced discomfort to patients[21], faster wire changes[22], and reduced overall treatment times[19, 23]. It appears, however, that these proposed advantages come at a cost to patient esthetics. Among children ages 9-14, all self ligating systems were considered significantly less attractive than traditional twin brackets with colored elastomeric ties. Furthermore, in all age groups, acceptability rates for any self-ligating bracket were 23-46% lower than traditional twin brackets with colored elastomeric ties. For some patients, the inability to select colors at each appointment may become an obstacle to accepting treatment with a self-ligating bracket. Though colored ties could be added to self-ligating brackets, many of the potential benefits would then be negated. In this study, three self-ligating brackets were selected, but as many variations in the design of self-ligating brackets exist, these brackets may not be representative of all self-ligating systems.

One surprising finding of this study was the overall high rating of shaped brackets in all age groups. Acceptability for shaped brackets was highest in the youngest age group at 70%, 25% higher in acceptability than traditional ceramic brackets. This preference over ceramic brackets diminished in the second age group, and appeared to level out in the third age group. This apparent preference for shaped brackets over ceramic brackets, especially in children 9-14, was also evident in subject rank lists. Thus it would appear that if an orthodontic practice were to offer an alternative bracket to their standard appliance for children and adolescents, WildSmiles™ would likely elicit more demand than a ceramic bracket.

CONCLUSIONS

1. Children and adult preferences for orthodontic appliances differ. Reducing metal show in appliances is not the driving factor for esthetics among the majority of children and adolescents.
2. Children's preferences for orthodontic appliances differ by age and sex. Older children tended to have a stronger preference for clear appliances than younger children. Shaped brackets are preferred most by younger patients and female patients.
3. The use of stainless steel brackets with colored ties and the use of clear tray aligners are highly accepted by all age groups.
4. Colored elastomeric ties contribute significantly to the attractiveness of orthodontic appliances for children and adolescents.

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REFERENCES

1. Sarver DM, Ackerman JL. Orthodontics about face: The re-emergence of the esthetic paradigm. Am J Orthod Dentofacial Orthop. 2000;117:575-6.

2. Keim RG, Gottlieb EL, Nelson AH, Vogels DS,3rd. 2007 JCO orthodontic practice study. part 1: Trends. J Clin Orthod. 2007;41:617-26.

3. Willems G, Carels CE. Developments in fixed orthodontic appliances. Ned Tijdschr Tandheelkd. 2000;107:155-9.

4. Russell JS. Aesthetic orthodontic brackets. J Orthod. 2005;32:146-63.

5. Redd TB, Shivapuja PK. Debonding ceramic brackets: Effects on enamel. J Clin Orthod. 1991;25:475-81.

6. Loftus BP, Artun J, Nicholls JI, Alonzo TA, Stoner JA. Evaluation of friction during sliding tooth movement in various bracket-arch wire combinations. Am J Orthod Dentofacial Orthop. 1999;116:336-45.

7. Omana HM, Moore RN, Bagby MD. Frictional properties of metal and ceramic brackets. J Clin Orthod. 1992;26:425-32.

8. Joffe L. Invisalign: Early experiences. J Orthod. 2003;30:348-52.

9. Djeu G, Shelton C, Maganzini A. Outcome assessment of invisalign and traditional orthodontic treatment compared with the american board of orthodontics objective grading system. Am J Orthod Dentofacial Orthop. 2005;128:292,8; discussion 298.

10. Meier B, Wiemer KB, Miethke RR. Invisalign--patient profiling. analysis of a prospective survey. J Orofac Orthop. 2003;64:352-8.

11. Ling PH. Lingual orthodontics: History, misconceptions and clarification. J Can Dent Assoc. 2005;71:99-102.

12. Poon KC, Taverne AA. Lingual orthodontics: A review of its history. Aust Orthod J. 1998;15:101-4.

13. Ziuchkovski JP, Fields HW, Johnston WM, Lindsey DT. Assessment of perceived orthodontic appliance attractiveness. Am J Orthod Dentofacial Orthop. 2008;133:S68-78.

14. Rosvall MD, Fields HW, Ziuchkovski J, Rosenstiel SF, Johnston WM. Attractiveness, acceptability, and value of orthodontic appliances. Am J Orthod Dentofacial Orthop. 2009;135:276.e1,12; discussion 276-7.

15. Keim RG, Gottlieb EL, Nelson AH, Vogels DS,3rd. 2008 JCO study of orthodontic diagnosis and treatment procedures, part 1: Results and trends. J Clin Orthod. 2008;42:625-40.

16. Harradine NW. Self-ligating brackets and treatment efficiency. Clin Orthod Res. 2001;4:220-7.

17. Sims AP, Waters NE, Birnie DJ. A comparison of the forces required to produce tooth movement ex vivo through three types of pre-adjusted brackets when subjected to determined tip or torque values. Br J Orthod. 1994;21:367-73.

18. Shivapuja PK, Berger J. A comparative study of conventional ligation and self-ligation bracket systems. Am J Orthod Dentofacial Orthop. 1994;106:472-80.

19. Turnbull NR, Birnie DJ. Treatment efficiency of conventional vs self-ligating brackets: Effects of archwire size and material. Am J Orthod Dentofacial Orthop. 2007;131:395-9.

20. Eberting JJ, Straja SR, Tuncay OC. Treatment time, outcome, and patient satisfaction comparisons of damon and conventional brackets. Clin Orthod Res. 2001;4:228-34.

LEGEND

Appliance/Tie Combination	Type of Appliance
GAC MicroArch®, clear ties	Standard Twin Stainless Steel
GAC MicroArch®, colored ties	Standard Twin Stainless Steel
WildSmiles™, clear ties	Stainless Steel Shaped
WildSmiles™, colored ties	Stainless Steel Shaped
GAC In-Ovation R®	Stainless Steel Self-Ligating
Ormco Damon 3™	Hybrid Self-Ligating
GAC In-Ovation C™	Ceramic Self Ligating
GAC Mystique®, clear ties	Ceramic
GAC Mystique®, discolored ties	Ceramic
Essix® (clear tray)	Clear Tray Aligner

Table 3.1: List of Appliance Images and Classification

Demographic Category	Response Rate Per Question	Demographic Groupings		Count	Relative Frequency Rate
Gender	100%	Male		58	41.7%
		Female		81	58.3%
Age	100%	Group 1	9 Years Old	5	3.6%
			10 Years Old	17	12.2%
			11 Years Old	23	16.5%
		Group 2	12 Years Old	18	12.9%
			13 Years Old	17	12.2%
			14 Years Old	14	10.1%
		Group 3	15 Years Old	24	17.3%
			16 Years Old	12	8.6%
			17 Years Old	9	6.5%

Table 3.2: Demographic Summary of Research Subjects.

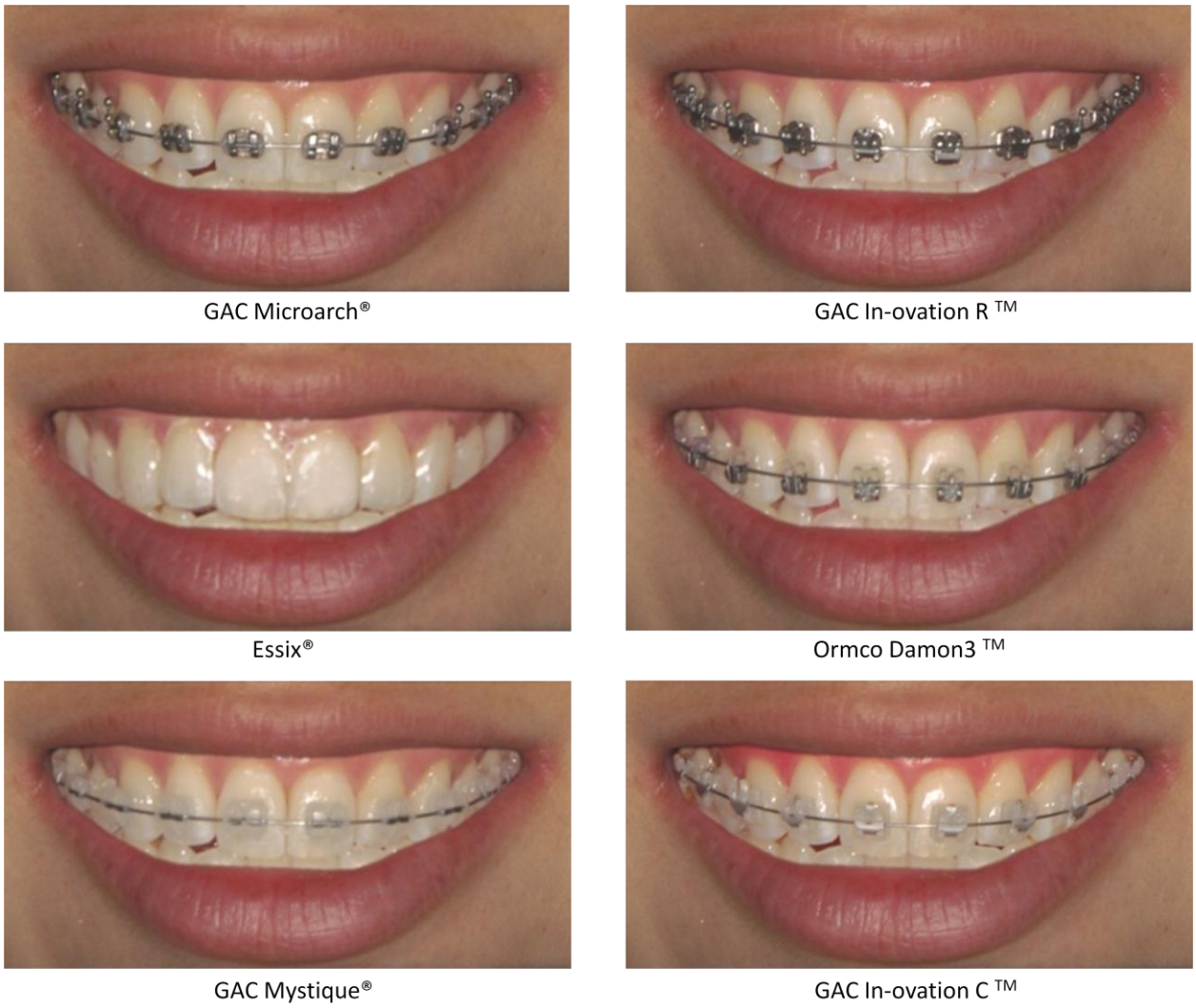


Figure 3.1: Images Acquired and Standardized in Previous Studies

Figure 3.2: Images of WildSmiles™ Shaped Brackets

Figure 3.3: Image of MicroArch® Brackets with Colored Elastomeric Ties

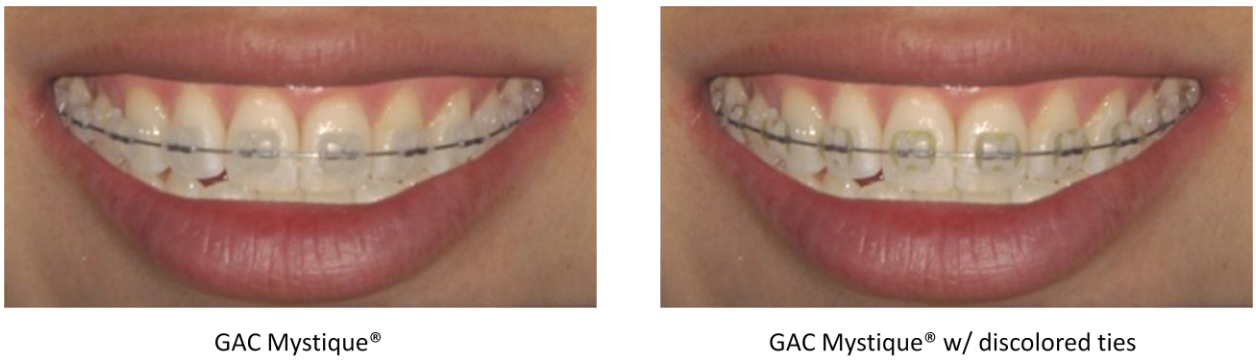
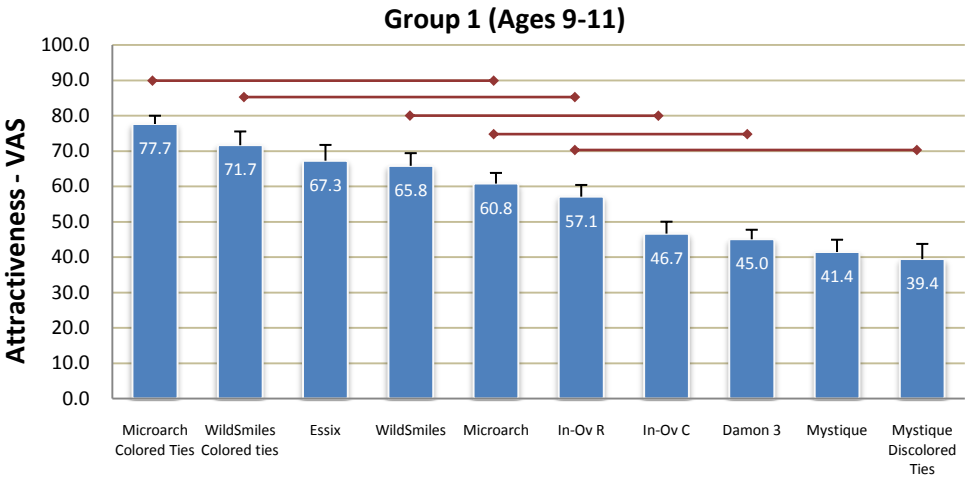
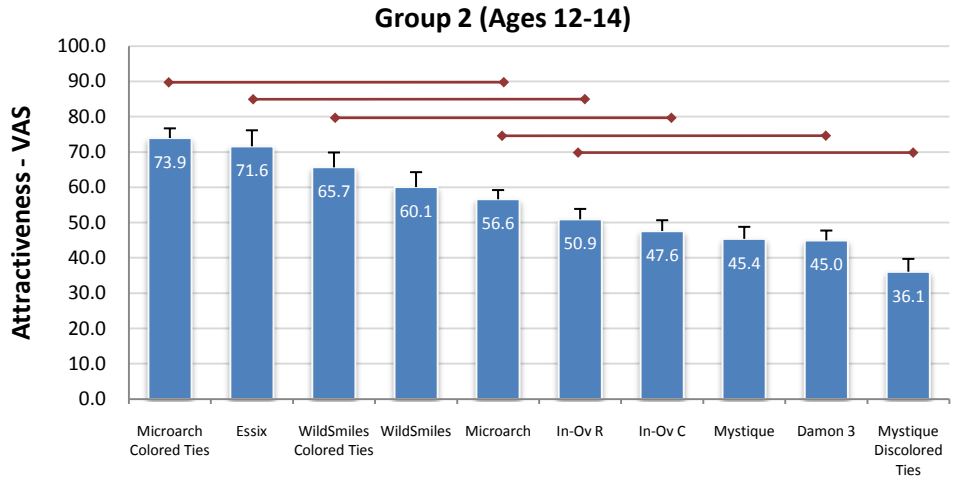


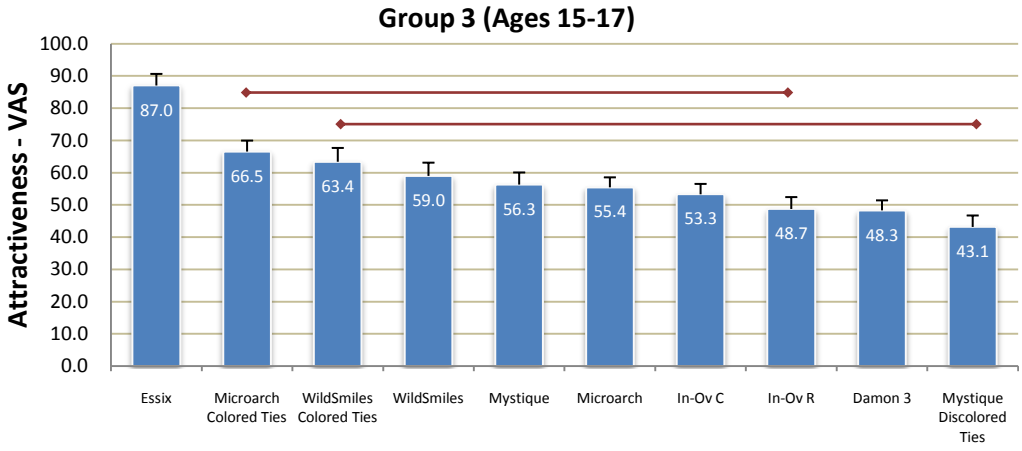
Figure 3.4: Clear Elastomeric Ties and Discolored Clear Elastomeric Ties on Mystique® Brackets.



A.

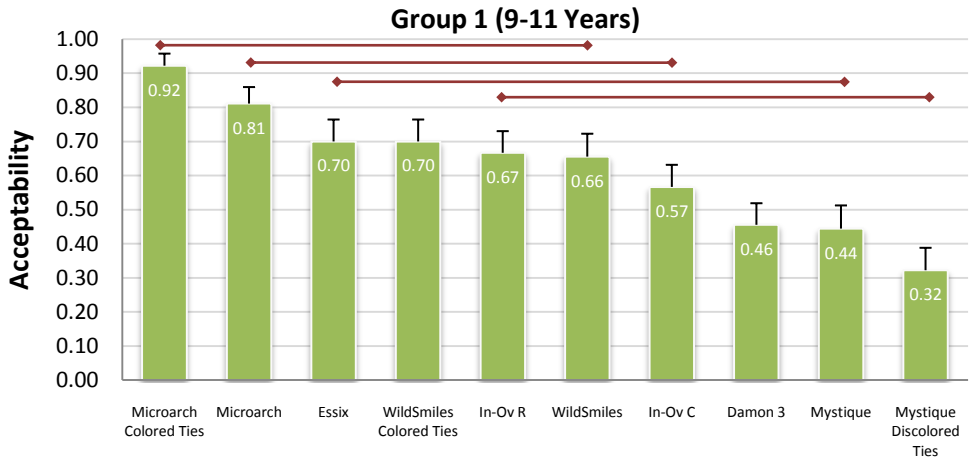


B.

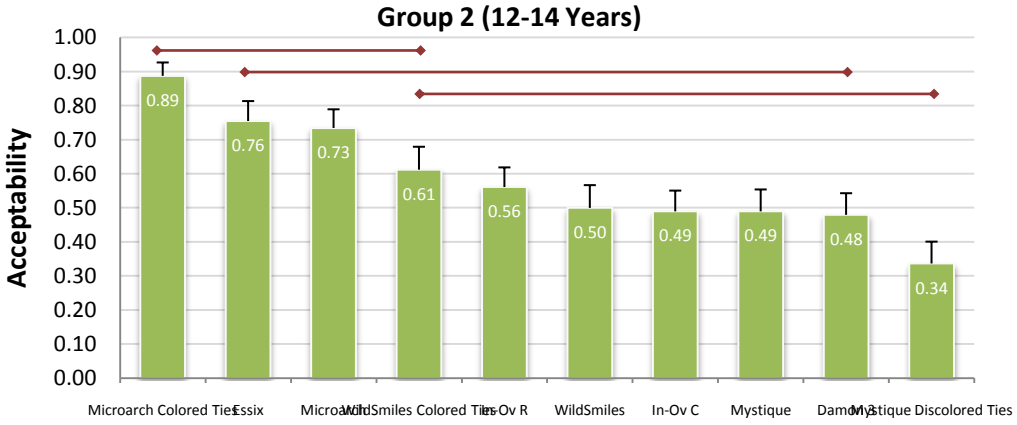


C.

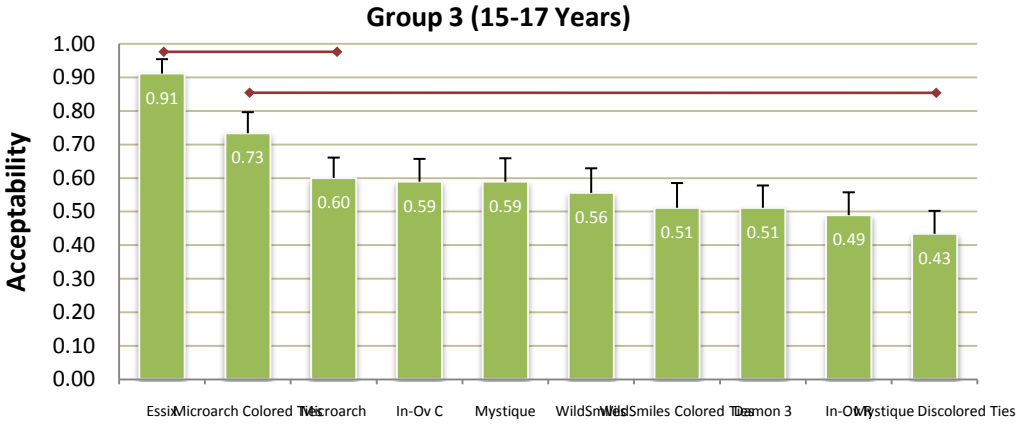
Figure 3.5 A, B, and C: Average VAS Ratings for Age Groups 1, 2, and 3. Appliances connected with overlying bars denote no difference in statistical significance.



A.

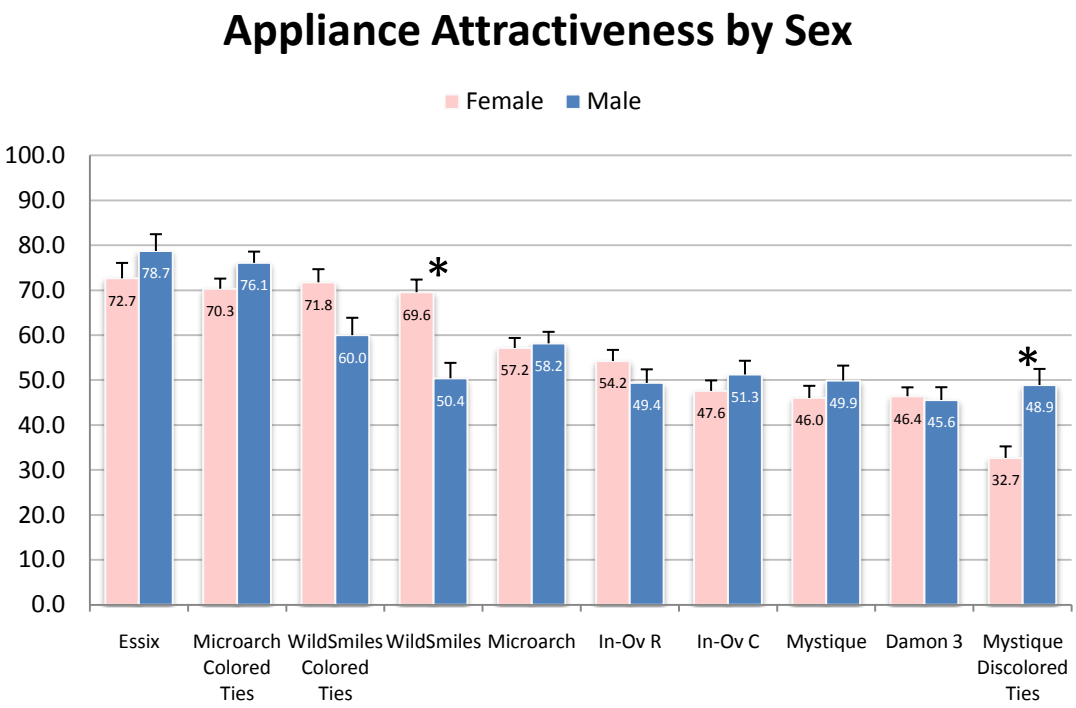


B.

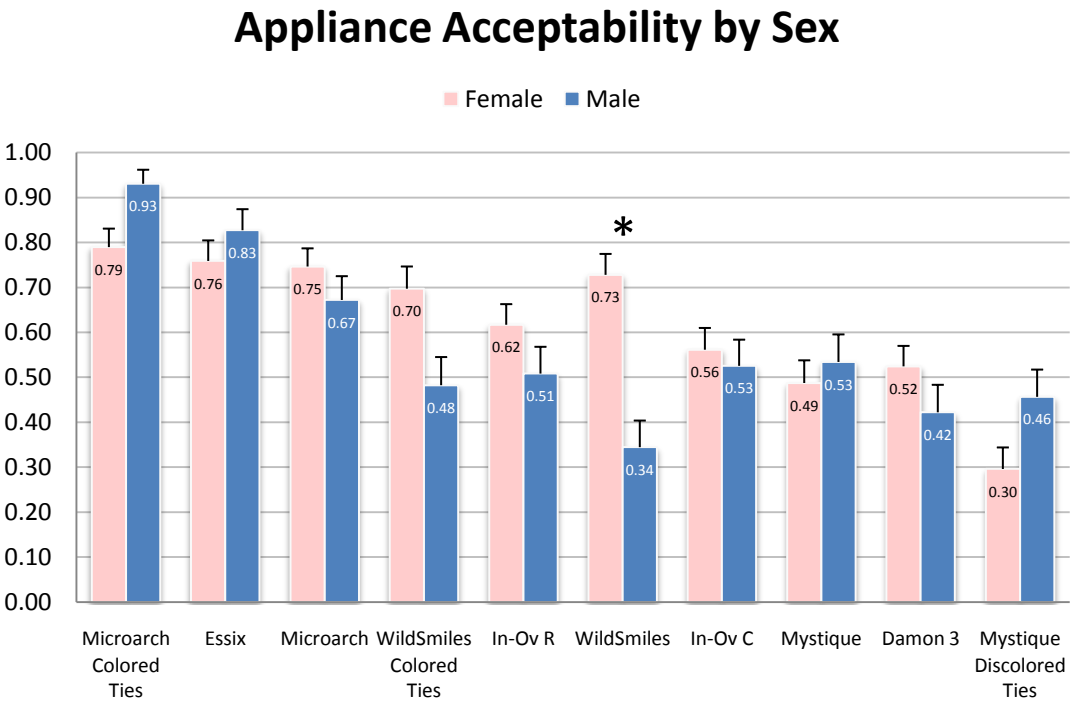


C.

Figure 3.6 A, B, and C: Average Acceptability Ratings for Age Groups 1, 2, and 3. Appliances connected with overlying bars denote no difference in statistical significance.



A.



B.

Figure 3.7 A and B: Average Attractiveness and Acceptability Ratings for Appliances by Sex. Comparisons designated with an asterisk are statistically significant at $p<.05$.

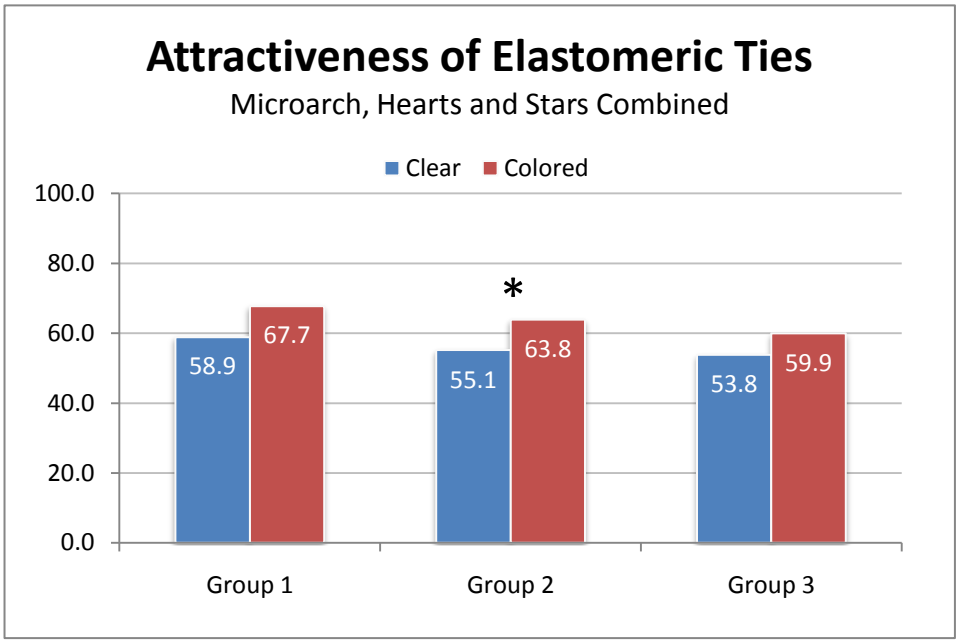
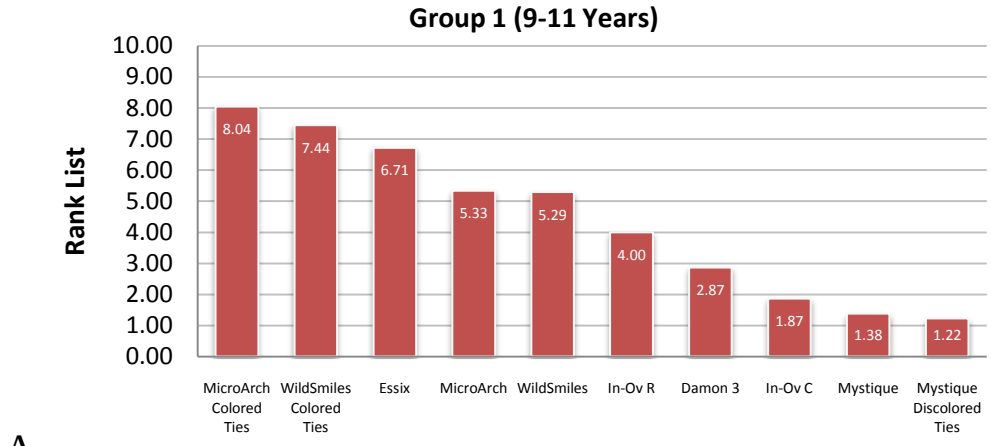
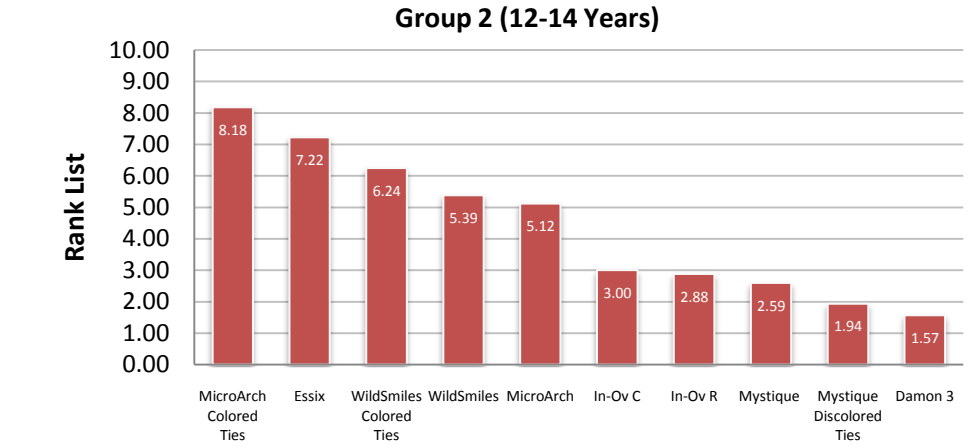


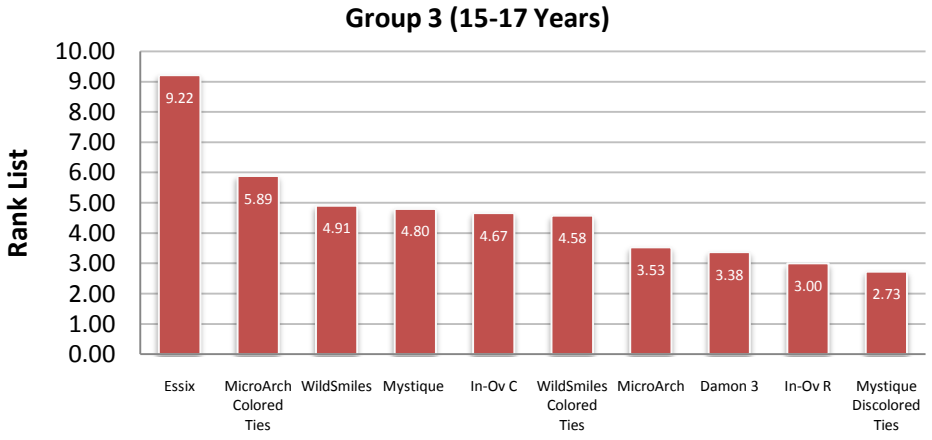
Figure 3.8: Average VAS Ratings of MicroArch®, WileSmiles™ Stars, and WildSmiles™ Hearts Brackets Designated with Colored or Clear Elastomeric Ties. Comparisons designated with an asterisk are statistically significant at $p<.05$.



A.



B.



C.

Figure 3.9 A, B, and C: Average Rank List Scores for Age Groups 1, 2, and 3. Higher average values indicate higher appliance preference.

CHAPTER 4

GENERAL CONCLUSIONS

The recent development and production of a wide variety of orthodontic appliances has increased treatment options for the patient consumer. As orthodontic providers become more aware of their patients' appliance preferences, they will be better able to cater to their patients' esthetic needs and increase the overall acceptability of orthodontic treatment. Though adult patients in general prefer appliances with less metal show, children and adolescents use a variety of factors when evaluating appliance esthetics. Appliance visibility, shape, and color all appear to influence children's preferences between age groups and between sexes. This study will allow providers to draw several conclusions regarding their non-adult patients.

1. Children and adult preferences for orthodontic appliances differ. Reducing metal show in appliances is not the driving factor for esthetics among the majority of children and adolescents.
2. Children's preferences for orthodontic appliances differ by age and sex. Older children tended to have a stronger preference for clear appliances than younger children. Shaped brackets are preferred most by younger patients and female patients.
3. The use of stainless steel brackets with colored ties and the use of clear tray aligners are highly accepted by all age groups.
4. Colored elastomeric ties contribute significantly to the attractiveness of orthodontic appliances for children and adolescents.

BIBLIOGRAPHY

Chenin DA, Trosien AH, Fong PF, Miller RA, Lee RS. (2003) Orthodontic treatment with a series of removable appliances. ***J Am Dent Assoc*** **134:1232-1239.**

Djeu G, Shelton C, Maganzini A. (2005) Outcome assessment of Invisalign and traditional orthodontic treatment compared with the American Board of Orthodontics objective grading system. ***Am J Orthod Dentofacial Orthop*** **128:292-8; discussion 298.**

Eberting JJ, Straja SR, Tuncay OC. (2001) Treatment time, outcome, and patient satisfaction comparisons of Damon and conventional brackets. ***Clin Orthod Res*** **4:228-234.**

Hain M, Dhopatkar A, Rock P. (2003) The effect of ligation method on friction in sliding mechanics. ***Am J Orthod Dentofacial Orthop*** **123:416-422.**

Harradine NW. (2001) Self-ligating brackets and treatment efficiency. ***Clin Orthod Res*** **4:220-227.**

Joffe L. (2003) Invisalign: early experiences. ***J Orthod*** **30:348-352.**

Keim RG, Gottlieb EL, Nelson AH, Vogels DS,3rd. (2008) 2008 JCO study of orthodontic diagnosis and treatment procedures, part 1: results and trends. ***J Clin Orthod*** **42:625-640.**

Keim RG, Gottlieb EL, Nelson AH, Vogels DS,3rd. (2007) 2007 JCO Orthodontic Practice Study. Part 1: Trends. ***J Clin Orthod*** **41:617-626.**

Ling PH. (2005) Lingual orthodontics: history, misconceptions and clarification. ***J Can Dent Assoc*** **71:99-102.**

Loftus BP, Artun J, Nicholls JI, Alonzo TA, Stoner JA. (1999) Evaluation of friction during sliding tooth movement in various bracket-arch wire combinations. ***Am J Orthod Dentofacial Orthop*** **116:336-345.**

Meier B, Wiemer KB, Miethke RR. (2003) Invisalign--patient profiling. Analysis of a prospective survey. ***J Orofac Orthop*** **64:352-358.**

Omana HM, Moore RN, Bagby MD. (1992) Frictional properties of metal and ceramic brackets. ***J Clin Orthod*** **26:425-432.**

Poon KC, Taverne AA. (1998) Lingual orthodontics: a review of its history. ***Aust Orthod J*** **15:101-104.**

Redd TB, Shivapuja PK. (1991) Debonding ceramic brackets: effects on enamel. ***J Clin Orthod*** **25:475-481.**

Rosvall MD, Fields HW, Ziuchkovski J, Rosenstiel SF, Johnston WM. (2009) Attractiveness, acceptability, and value of orthodontic appliances. ***Am J Orthod Dentofacial Orthop*** **135:276.e1-12; discussion 276-7.**

Russell JS. (2005) Aesthetic orthodontic brackets. ***J Orthod*** **32:146-163.**

Sarver DM, Ackerman JL. (2000) Orthodontics about face: the re-emergence of the esthetic paradigm. ***Am J Orthod Dentofacial Orthop*** **117:575-576.**

Shivapuja PK, Berger J. (1994) A comparative study of conventional ligation and self-ligation bracket systems. ***Am J Orthod Dentofacial Orthop*** **106:472-480.**

Sims AP, Waters NE, Birnie DJ. (1994) A comparison of the forces required to produce tooth movement ex vivo through three types of pre-adjusted brackets when subjected to determined tip or torque values. *Br J Orthod* 21:367-373.

Tecco S, Di Iorio D, Cordasco G, Verrocchi I, Festa F. (2007) An in vitro investigation of the influence of self-ligating brackets, low friction ligatures, and archwire on frictional resistance. *Eur J Orthod* 29:390-397.

Turnbull NR, Birnie DJ. (2007) Treatment efficiency of conventional vs self-ligating brackets: effects of archwire size and material. *Am J Orthod Dentofacial Orthop* 131:395-399.

Willems G, Carels CE. (2000) Developments in fixed orthodontic appliances. *Ned Tijdschr Tandheelkd* 107:155-159.

Ziuchkovski JP, Fields HW, Johnston WM, Lindsey DT. (2008) Assessment of perceived orthodontic appliance attractiveness. *Am J Orthod Dentofacial Orthop* 133:S68-78.