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The Prevalence of the Need for Esthetic Crown Lengthening in Post Orthodontically Treated Subjects

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THE PREVALENCE OF THE NEED FOR ESTHETIC CROWN LENGHENING IN POST ORTHODONTICALLY TREATED SUBJECTS

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science at Virginia Commonwealth University

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Abstract

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The problem of excess gingival display is difficult to diagnose and treat. By studying one aspect of excess gingival display, namely the size relationships of the clinical crowns of teeth, we can begin to quantify reasonable goals of therapy. In this study, two hundred plaster models were used as subjects. These represented two hundred patients before and after orthodontic therapy. The six anterior teeth were measured for length and width and compared to known ideals. Teeth that did not meet ideal standards may require treatment. It was found that the mean tooth length after orthodontic therapy was

approximately two millimeters shorter than ideal. The length of maxillary central incisors did not increase over the course of therapy. Eighty-five to ninety percent of maxillary central incisors exceeded allowable tooth width-to-length ratios. Twenty-nine to thirty percent of central incisors exceeded one hundred percent in their width-to-length ratio. Sixty-eight percent of patients displayed asymmetry in gingival architecture.

Introduction

Prevalence information exists for most diseases and conditions. Clinicians understand that data regarding prevalence are helpful in that they allow a practitioner to know how often they should be observing a given condition. If they observe it more or less than the accepted prevalence data indicate, it may be useful to reevaluate their methods for diagnosing that condition. Prevalence information regarding dental esthetics is very scarce. This is largely due to the fact that a subjective field like esthetics is hard to study objectively. Fortunately, past research has indicated that esthetics is not entirely a subjective field. There are rules and values that stay within observed ranges and may be considered "ideal." This allows us to compare data gathered in new studies to these values and then to determine how often variations from them occur.

Early research to define these values was done by Levin[1] and Lombardi[2], who developed the concept that mathematic proportions described by the ancient Greeks many centuries ago could be used even today to define the ideal in dental esthetics. Ward[3] developed a new set of proportionate values that today are generally accepted by dentists as the ideal. The preferred width to height ratio in his study was 78% though the acceptable range was 66% to 80%. He also found that the width relationships of the anterior teeth should be at a ratio of 70% versus the Golden Proportion (62%), as developed by the ancient Greeks. Gillen[4] validated the existence of consistent ratios in the sizes of teeth regardless of race

and gender and found them to be in the same ranges described by Ward[3]. Ahmad[5] described the Gingival Aesthetic Line which is the line connecting the apices of the gingival scallop for the maxillary anterior teeth. This line should be parallel to the interpupillary line and both central incisors and canines should have a scallop tangent to this line with the lateral incisor lying about 0 to 1 mm coronal to it. While the author allows for some variation in the position of the teeth, there should be symmetry in the gingival composition as it relates to this line. Touati[6] proposed that each of the anterior maxillary teeth plays a specific esthetic role. The central incisors provide stability and balance. The laterals provide charm, and the canines bring strength to the esthetic zone.

Townsend[7] reviewed many gingival aspects of the ideal smile. Canines and central incisors should be the same length and lateral incisors 1 to 2 mm shorter. The most apical part of the gingival scallop should reflect the angle of the long axis of the tooth. There should be an interdental papilla of 4.5 to 5.0 mm from the tip of the papilla to the depth of the marginal scallop. Townsend[7] also said that the tooth length for a maxillary central incisor averages 13.5 mm, 12.0 mm were average for a maxillary lateral incisor, and 13.0 mm was the average length for a maxillary canine. McGuire[8] provided a protocol for diagnosing possible esthetic problems. He reported that the average tooth lengths for the maxillary anterior were 11 to 13 mm, 10mm, and 11 to 13 mm for the centrals, laterals, and canines, respectively. Often discussed in relation to the topic is the concept of altered passive eruption. The idea of two stages of eruption, one towards to occlusal plane and one where the gingival crevice moves apically (passive eruption), was first elucidated by Gottlieb and Orban[18] in 1933. It was further reported in a study by

Volchansky[17] regarding some risk factors for Vincent's disease that 12.1% of 1,025 patients studied had some form of "delayed passive eruption." An in depth definition and description of altered passive eruption, a potential mechanism for the esthetic situation studied in this report, was developed by Coslet et al[11]. While the protocol is extremely valuable for the practitioner, it does not include any reference to prevalence of these problems. Tjan[12] reported that 10.57% of their study population had a high smile line as defined in their study and that a further 68.94% had an average smile. Chechi[131] found that up to 3 mm of gingival tissue may show in those with high smile lines before esthetics were compromised.

In executing this study, some other definitions are required. The ideal tooth sizes have been described, but these may not be the sizes most often seen in patients. First, normal tooth size must be defined. Then we must determine which value is more important to us, the normal length or the ideal length. Wheeler's[14] text on dental anatomy gives values normal length for the maxillary anterior teeth, however this is an average length measured on extracted teeth, and it does not allow for any soft tissue attachment to the crown. The reported normal values are 10.5 mm. 9.0 mm, and 10.0 mm for central incisors, laterals, and canines, respectively. He also reported a normal length of 8.5mm for maxillary first and second premolars. Löe's[15] description of the normal gingival attachment could be combined with this data to give an ideal clinical tooth size. It was found that there was an average of 0.5 to 2 mm of soft tissue attachment, so minimum normal length would be 8.5 mm, 7 mm, and 8 mm, for maxillary central incisors, lateral incisors, and canines, respectively and 6.5 mm for maxillary premolars. Gargiuolo[16]

described a zone of attachment measuring an average of 2.04 mm and added that 0.69 mm of sulcus depth could usually be found in the absence of inflammation. Both Gillen[4] and Pearson[17] made measurements of teeth on plaster models with calipers. However, their study questions were distinctly different than in the present study and were mostly concerned with tooth size from a prosthetic standpoint. A final historical note would be the concern about the age of the patient and the completion of eruption of the teeth to be studied. Volchansky[18] found that eruption of the tooth was completed by age 12 for the maxillary central incisors and canines, and that maxillary lateral incisors continued to demonstrate minor changes in gingival margin position when the subjects had reached 16 years of age.

The purpose of this study is to apply accepted standards and determine the prevalence of the need for esthetic crown lengthening in a population of patients recently completing orthodontic therapy.

Methods

The study was designed to evaluate the tooth size, both length and width for subjects who have undergone orthodontic treatment at the VCU School of Dentistry. Subjects were plaster models fabricated by the VCU department of Graduate Orthodontics. Inclusion criteria were that those subjects selected had completed orthodontic movement of the maxillary central incisors (#8 and 9), lateral incisors (#7 and 10), and canines (#6 and 11). All teeth in the study were measured on the plaster models using digital calipers.

Data obtained from these measurements were compared to each other and to accepted "ideal" values. The ideal tooth length was defined as indicated by McGuire[8], 11 to 13 mm for centrals, 10 mm for laterals, and 11 to 13 mm for canines, as those include a wide enough range to account for normal variation. Normal tooth length as described by Wheeler[14] was also used for comparison, including an allowance for soft tissue of 2.0 mm as indicated by Löe[15]. Tooth width-to-length ratio is compared as it has been found to be more consistently accepted as a standard for tooth size. This study considers a maximum of 80% width-to-length ratio to qualify as within normal limits. Ideal papillary height was defined as 4.5 to 5.0 mm as described by Townsend[7], and this is also the measure for depth of the gingival scallop. It was determined how many teeth had scalloping of this depth. Those values that differ by a significant amount place that

subject and that tooth into the group of those requiring esthetic crown lengthening. These data were then be compiled to give a prevalence value for the need for esthetic crown lengthening on a subject and tooth level.

Measurements were done with a digital caliper and were taken for tooth number 5, 6, 7, 8, 9, 10, 11, and 12 on post-orthodontic models and on pre-orthodontic models for numbers 6 – 11. The measurements were from the gingival margin to the incisal edge, and both above and below a line drawn between the tips of the papillae on either side of these teeth. They were also measured for the distance between the interproximal contacts as seen from the frontal view. This was accomplished by marking the mesial and distal dimension of each tooth as seen from directly in front of the model on a sheet of graphing paper. The distance in as seen from the front was then measured on the paper with digital calipers. Calculations made from the data were a ratio of the gingival versus the incisal measurements, the ratio of width to height, and comparison of all measurements to accepted normal values. Central incisors with a greater than 80% width:length ratio were placed in the group requiring esthetic crown lengthening. Teeth with at least one millimeter difference in length between symmetrical teeth, except for laterals, were also placed in this group, as were canine:central length discrepancies of greater than one millimeter. Teeth with less than four millimeters of depth of scallop were also included. Age and gender of the subjects from which the models were developed were also tested as potentially significant cofactors in excessive gingival display.

Statistical analysis was to determine the proportion, which was then converted to a percentage, of subjects whose values lie outside of the accepted normal values for tooth

sizes and ratios. Tooth-to-tooth values were tested for significance by t-test, pre- and post-orthodontic measurements were tested by paired t-test. Age was tested by ANOVA analysis and gender by the McNemars test for significance. Significance was defined as $p<0.05$.

Results

Two hundred plaster models from the VCU Graduate Orthodontic Clinic were measured according to the above guidelines. At the time of model fabrication, 101 of 166 patients for whom age data could be located were younger than 18 years old, 69 were younger than 16years old. There were 119 female patients and 81 males, see Table 1. Age could not be determined for a large number of subjects as their records are inactive and no longer kept on file in the orthodontic department. Gender differences were not significant.

Age Range (years)	Number of Subjects
8 – 10	5
11 – 15	64
16 - 20	57
21 – 30	20
31 +	10
unknown	44

Table 1 – Age distribution

Clinical crown lengths had mean post-orthodontic values of 8.7mm for #6, 7.8mm for #7, 9.3mm for #8, 9.4mm for #9, 7.9mm for #10, and 8.7mm #11 (Table 2). Mean width for each tooth as measured from a frontal view was 6.8mm for #5, 4.3mm for #6, 5.6mm #7, 8.7mm #8, 8.8mm #9, 5.8mm #10, 4.1mm #11, and 6.9 #12 (Table 3).

Tooth number	Normal length (mm)	Ideal length (mm)	Mean observed pre-orthodontic length (mm)	Standard deviation	Mean observed post-orthodontic length (mm)	Standard deviation	Significance
6	10	11–13	7.7	±2.5	8.7	±1.5	p<0.0001
7	9	10–12	7.4	±1.1	7.8	±1.1	p<0.0001
8	10.5	11–13	9.3	±1.1	9.3	±1.1	p>0.05 (NS)
9	10.5	11–13	9.4	±1.1	9.4	±1.1	p>0.05 (NS)
10	9	10–12	7.5	±1.1	7.9	±1.1	p<0.0001
11	10	11–13	7.7	±2.6	8.7	±1.3	p<0.0001

Table 2 – Tooth length before and after orthodontic therapy

Tooth number	Post-orthodontic length (mm)	Post-orthodontic width (mm)	Mean observed post-orthodontic width:length (%)	Standard deviation
7	7.8	5.6	73	±0.12
8	9.3	8.7	94	±0.13
9	9.4	8.8	95	±0.13
10	7.9	5.8	76	±0.13

Table 3 – Post orthodontic tooth width-to-length ratios

Comparison of data from each tooth yielded further information. Lateral incisors and canines were significantly longer following orthodontic therapy compared to pre-treatment values ($p<0.0001$). Central incisors did not have a significant increase in crown length following orthodontic therapy ($p>0.05$). Table 4 summarizes comparison of observed crown width-to-length ratios compared to ideal values. Calculated width-to-length ratios for incisors were a mean of 73% for #7, 94% for #8, 95% for #9, and 76% for #10. For tooth #7, 24% had a width-to-length ratio greater than 80%. 85% of patients had a ratio greater than 80% for #8, 90% for #9, and 33% for #10. By tooth, 2% of #7, 29.5% of #8, 30% of #9, and 4% of #10 had at least 100% width-to-length ratio. By

patient, 36.5% of patients had at least one central incisor with a width-to-length ratio of at least 100%.

Tooth number	Teeth with post-orthodontic width:length >80%	Teeth with post orthodontic width:length ≥ 100%
7	24%	2%
8	85%	29.5%
9	90%	30%
10	33%	4%

Table 4 – Percentage of teeth with short clinical crowns following orthodontics

68% of patients had an asymmetry of at least one millimeter between the tooth and its antimer, or between a maxillary canine and its ipsilateral central incisor. As can be seen in Table 5, 818(68.6%) of teeth had a scallop measuring 2 – 4mm in depth, 177(14.8%) of scallops were 0 – 2mm deep, and 197(16.5%) were greater than 4mm in depth. Table 6 summarizes results from Gingival Aesthetic Line (GAL) analysis. Of 391 lateral incisors compared to canine and central position, the gingival margin for 333 of them was found from 0 – 1mm from the GAL. Twenty-four incisors were found actually apical to this line, and 34 of them were at a distance of greater than 1mm from this line.

	Scallop depth		
Tooth Number	0-2mm	2-4mm	4+mm
6	24	130	42
7	49	137	14
8	22	132	46
9	19	142	39
10	47	135	18
11	16	142	36
Total	177	818	197

Table 5 – Scallop Depth

Lateral incisor relationship to Gingival Aesthetic Line		
Apical to GAL	0-1mm coronal to GAL	>1mm coronal to GAL
24	333	34

Table 6 – Number of lateral incisors with their relationship to GAL

Discussion

The harmony and flow of an esthetic smile are derived from a summation of all of its parts. This study only examined one particular aspect of the esthetic smile; that of tooth size relationships. There are rules and guidelines in the literature that aid us in creating an esthetic smile when there is a compromise. Using these guidelines, this study determined the percentage of subjects in the defined population who may benefit from esthetic crown lengthening procedures.

It was found that mean tooth length was well within the range of those values described by Wheeler[14] for each tooth. This was only true once some dimension of soft-tissue attachment was provided for. The value selected was 2mm, the maximum normal amount described by Löe[15]. Without accounting for soft-tissue, most teeth in the present study would be too small, even compared to normal. Upon comparing mean observed values to accepted ideals, as presented by Townsend[7] and McGuire[8], lengths were from 1.7 to 2.3 mm too short, with the canines and lateral incisors averaging more than 2 mm shorter in length than the ideal. Despite these dramatic differences, it was determined that a proportionate comparison, that of width-to-length ratio, would be most reliable as a true indicator of ideal tooth size. This is based on current esthetic philosophy as well as past research[3,4].

Findings regarding this proportionate comparison were even more evident in their discrepancy from ideal values than were those for tooth length alone. Mean ratios of 94 - 95% were discovered for central incisors, which compare favorably if the same analysis is done using Wheeler[14] and Löe[15] as a frame of reference. Lateral incisors had a mean ratio of 73%, which is allowable under both normal and ideal definitions. The discrepancy between normal and ideal was dramatic indeed for central incisors. It was found that 85 – 90% of central incisors exceeded the allowed 80% tooth width-to-length ratio. When taken even further, 29.5 – 30% of central incisors recorded at least 100% width-to-length ratio. This means that nearly a third of central incisors were at least as wide as they were long. No literature can be found supporting this relationship as an esthetic ideal. See Figures 1 through 3 for an image of what different width-to-length ratios might look like.

Figure 1 – Tooth width-to-length ratio of 66%

Figure 2 – Tooth width-to-length ratio of 80%

Figure 3 – Tooth width-to-length ratio of 100%

Less evident differences were discovered on evaluating scallop depth. Townsend[7] stated that scallop depth should be 4.5 – 5 mm. As scallop depth is synonymous to papilla height, another common guide is that the papilla should be one-half the height of the crown. Under either criteria, at least 83% of the teeth in this study failed to reach them. Only 16.5% of teeth had a scallop depth of at least 4mm, and as average crown length for central incisors was 9.3 – 9.4 mm, even 4 mm would be too short. There are several factors at work in this category of findings. First, if soft tissue is more coronally positioned than it should be, it will be on a flatter portion of the crown and because of that will have a flatter scallop. The second may actually be the more salient in this patient population. This is the probable presence of some gingival inflammation at the time of model fabrication. Models were made at removal of orthodontic appliances and signs of inflammation are a common finding at this appointment. This inflammation could result in enlarged, bulbous papillae and even some enlargement of marginal tissues. Said enlargement would affect papillary measurements and even potentially alter length measurements. This effect was anticipated, and models that were very evidently bulbous in their papillary and marginal architecture, were not included. Notwithstanding these precautions, some measurements may have been affected, as gingivitis is impossible to diagnose on plaster models. The potential for inflammatory change as a confounding element makes a second phase to this study a necessity. The study should be repeated on live patients to allow evaluation of the gingival tissue itself.

Another parameter that was difficult to quantify was that of the Gingival Aesthetic Line (GAL) relationship. Without a pupillary line for comparison, a line was

simply drawn between the apical extent of canine and maxillary central incisor marginal scallops. When canines were short, which was often the case, this line would not possibly be parallel to the interpupillary line. This also created an unusual morphology to the GAL and affected the lateral incisor position relative to the other two teeth. With the acknowledged difficulties, it was found that 85.2% of lateral incisors were in a proper relationship to the GAL. Only 8.7% of lateral incisors had more than 1 mm of soft tissue between the apex of the scallop and the GAL and only 7.2% were positioned apically from this line. As stated previously, the canines had a marked effect on this relationship, and in many cases it was the canine that was responsible for the discrepancy.

Another guideline that cannot be overlooked is the need for symmetry and harmony in the smile. In the present study, it was found that 68% of patients had an asymmetry in the length of canines compared to their antimer, central incisors compared to their antimer, and central incisors compared to ipsilateral canine. As defined in this study, an asymmetry was a discrepancy of at least 1 mm between the lengths of compared teeth. This asymmetry was very evident when comparing central incisors, as they are adjacent to one another and the dominant teeth in the smile. Surprisingly, the discrepancies in the canines were also immediately evident and were seen with regularity. It is undetermined whether these asymmetries arise from operator positioning or from some other source, but a lot of asymmetry was observed. This concept of harmony needs to be extended to include first premolars as well, though the ideal is not defined objectively in the literature. Figure 4 shows a model displaying some of the typical gingival asymmetry.

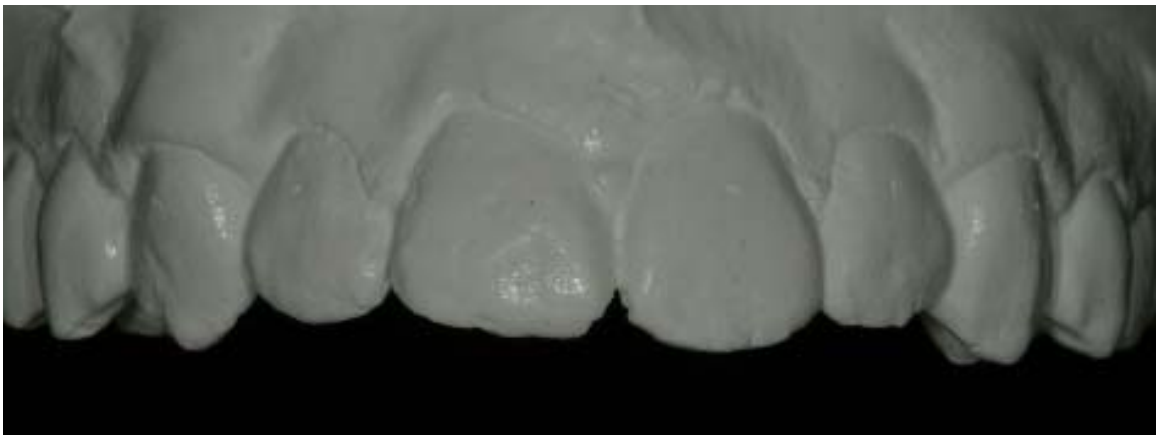

Figure 4 – Gingival asymmetry following orthodontic therapy

Our finding that the maxillary central incisors did not increase in length over the course of therapy may be simply due to lack of movement in the centrals while canines and lateral incisors were repositioned. This is purely speculation as no attempt was made to analyze tooth movement performed, only the fact that anterior teeth were moved. It may prove true that moving the central incisors may have caused a change in the position of the gingival margin for those teeth. As it is, it is important that the marginal tissue did not change its position. This may indicate some stability of the marginal position of the soft tissue and increase the validity of the findings of this study as they relate to the central incisors.

The ideal length of premolars was determined entirely according to data from Wheeler[14] combined with Löe[15]. There need to be some numerical guidelines in place regarding relationships between the canines to first premolars and first premolars to second premolars.

The final issue to be discussed is that of age and its role in tooth length. Volchansky[18] found that the marginal soft-tissue position did not change after the age of 12 in maxillary central incisors and canines in 237 patients. This was a non-longitudinal study of children up to16 years of age. The present study agreed with Volchansky's findings when considering the maxillary central incisors. Regarding the age when passive eruption should cease, Volchansky[10] found it to be at approximately 24 years of age in one study, though it was not clear for which teeth this was true. Tooth length in maxillary central incisors did not change from pre-orthodontic values in this study. However, length of maxillary lateral incisors and canines did change. It can be contended that the values for the central incisors can be considered accurate, despite the possible presence of inflammation, as pre- and post-orthodontic mean tooth lengths are virtually identical. As the central incisors are the key pillars to the esthetic smile, all other tooth positions should be determined and placed according to them.

Regarding the etiology of what we are seeing in this study. It is impossible, without proper determination of incisal edge position, tooth wear, and location of the cementoenamel junction, to properly attribute these findings to altered passive eruption, altered active eruption, incisal edge wear, or some other cause. It is enough to identify the prevalence of the tooth size problem in this study and determine more about the etiology in additional, live-subject studies.

Along with the potential weaknesses already discussed, possible inflammation and age questions, there is a very real weakness to this report. Namely, the majority of components to the esthetic smile are unevaluated in the present study. There has been no

allowance made for facial symmetry, labial curve, gingival display, position of midlines, buccal corridor display, location of the cementoenamel junction, or incisal edge position. Nor has there been any attempt to determine absolutely the definitive therapeutic modality for each case. This is a study to identify and define a particular piece of the esthetic puzzle. Further studies should be done that evaluate the total smile and tooth relationships.

This study does present some important findings and issues related to esthetics. It also raises some questions regarding the use of ideal guidelines versus normal anatomy. The majority of subjects in this study fell within normal ranges, but few met acceptable ideal criteria. Clinicians must work side-by-side with each other and with patients to determine exactly what the goals and expectations will be and if they can be met.

Conclusions

The following conclusions can be drawn based of the findings of this study. In this study,

1. Mean tooth length was found to be 1.7 – 2.3 mm shorter than ideal value.
2. Mean length of maxillary central incisors did not increase during the time interval between pre- and post orthodontic therapy measurements.
3. Mean tooth width-to-length ratio was 94 – 95% for maxillary central incisors compared to the ideal ratio of 80%.
4. 85 – 90% of maxillary central incisors exceeded the ideal of 80% width-to-length ratio.

5. 29.5 – 30% of maxillary central incisors exceeded 100% width-to-length ratio.
6. 68% of patients were found to have an asymmetry of at least one millimeter between adjacent central incisors, canine antimers, or the central incisor compared to its ipsilateral canine.

It would appear based on the findings of this study that up to 90% of post-orthodontics patients might benefit esthetically from crown lengthening procedures.

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