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Effects of Unilateral Extraction Treatment on Arch Symmetry and Occlusion

Theodore William Struhs
Virginia Commonwealth University

School of Dentistry
Virginia Commonwealth University

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EFFECTS OF UNILATERAL EXTRACTION TREATMENT ON ARCH SYMMETRY
AND OCCLUSION has been approved by his committee as satisfactory completion of
the thesis or dissertation requirement for the degree of Master of Science

---

Dr. Steven J. Lindauer, Thesis Director, Chairman Department of Orthodontics, School of Dentistry

---

Dr. Bhavna Shroff, Committee Member, School of Dentistry

Dr. Omar Abubaker, Committee Member, School of Dentistry

Dr. Eser Tüfekçi, Committee Member, School of Dentistry

Dr. Steven J. Lindauer, Chairman Department of Orthodontics, School of Dentistry

---

Dr. Laurie Carter, Director of Advanced Dental Education, School of Dentistry

---

Dr. F. Douglas Boudinot, Dean of the School of Graduate Studies

June 21,2005

EFFECTS OF UNILATERAL EXTRACTION TREATMENT ON ARCH SYMMETRY

AND OCCLUSION

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

by

THEODORE WILLIAM STRUHS
BS, Colorado State University, 1996
DDS, Virginia Commonwealth University, 2003

Director: STEVEN J. LINDAUER, D.M.D., M.D.SC.
PROFESSOR AND CHAIRMAN, DEPARTMENT OF ORTHODOTNICS

Virginia Commonwealth University
Richmond, Virginia
June 2005

<u>Acknowledgement</u>

I offer my most sincere thanks to Dr. Steven J. Lindauer for his support and guidance on this project. My initial interest and subsequent love for the orthodontic profession grew largely because of your guidance and example. The opportunity to learn from and work with you has been a pleasure and truly an honor. Thank you for the years of mentorship. A great deal of gratitude goes to my other thesis directors Dr. Shroff, Dr. Tüfekçi, and Dr. Abubaker. You all offered your knowledge and are each responsible for a significant part of my education.

I give my love and thanks to my family. Thank you to my sons, Carter and Braden, for every day making me smile. Thanks for reminding me that there is always time to have fun. Most of all I would like to thank my wife, Julie, for her endless love and support. This couldn't have happened without you. You are greatly appreciated and loved.

Table of Contents

List of Tables

List of Figures

<u>Abstract</u>

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Professor and Chairman, Department of Orthodontics, School of Dentistry

Occlusal asymmetries are common in orthodontic patients. A treatment option for

correcting moderate asymmetries is asymmetric extractions. This study evaluated post-

treatment dental arch symmetry in patients treated with unilateral premolar extractions.

Post-treatment casts of 60 patients were divided into four treatment groups based on the

history of occlusal asymmetry and the treatment plan. DesignCAD3000 software

(Upperspace Corporation, Pryor, OK) was used to evaluate asymmetrically treated arches

for symmetry. The four treatment groups were compared to identify differences in arch

asymmetry based on treatment. The lateral incisor and canine were found to be more

vi

palatal on the extraction side in patients treated with unilateral extractions (P < .001). Arch

length increased (P < 0.001) and area under the arch decreased (P < 0.01) on the extraction

side. On average, patients with asymmetric extractions did not finish with more arch

asymmetry than those without asymmetric extractions.

Introduction

The orthodontic treatment of patients presenting with occlusal asymmetries can be challenging for even the most experienced clinicians. Orthodontic treatment strategies to resolve asymmetric occlusal relationships include asymmetric mechanics, asymmetric extractions, and/or asymmetric surgical movements. When extractions are performed unilaterally, it may be difficult to maintain arch symmetry. This could result in uncoordinated maxillary and mandibular arches or in arches that are coordinated but both asymmetric.

Dental asymmetry

Sheats et al[1] reported that the prevalence of molar occlusions that are asymmetric by $^1/_2$ cusp or more is 10% to 13% in adolescent populations, and by one full cusp in 0.7% to 2.6% of this group. In orthodontic patients prior to treatment, the prevalence of molar asymmetry was found to be 18% in a mixed dentition sample and 25% in a permanent dentition sample. Maxillary to mandibular dental midline discrepancies were more common, occurring in 21% of the general population and 46% of orthodontic patients.[1] Studies have shown that mandibular midline deviations occur approximately twice as often as maxillary deviations.[1-3]

The most challenging and important step in treating an occlusal asymmetry is making the correct diagnosis. Once a functional shift is ruled out, it must be determined whether the asymmetric tooth position is due to a dental or a skeletal discrepancy.[4,5] Although dentofacial asymmetries can be the result of a skeletal asymmetry,[6] reports indicate that there is often no significant relationship between skeletal/facial asymmetries and dental asymmetries.[3,5] The contributing components of the Class II subdivision malocclusion have been reported to be largely dentoalveolar, with the mandibular first molar positioned more distally on the Class II side.[3,7] This is consistent with reports that a lower midline deviation is more frequently observed than an upper deviation in cases that lack midline coincidence.

Minor asymmetries can often be successfully treated with asymmetric orthodontic mechanics. The asymmetric movements possible, however, are limited in scope and often associated with relatively high levels of unwanted side effects.[8,9] The clinician, therefore, may not see these mechanics as a practical solution to correct moderate or severe asymmetries.

Unilateral extraction may be chosen as a treatment option when occlusal asymmetries are too severe to be treated with asymmetric mechanics alone but when surgical movements are not indicated or are not possible. One advantage of unilateral extraction is that the actual treatment mechanics can then proceed symmetrically with fewer side effects.[4,9,10] Occlusal asymmetry and dental midline deviations occur more commonly in Class II patients.[11] The most common asymmetric extraction patterns, therefore, take into account that more tooth structure usually needs to be removed from the

maxillary arch. One maxillary premolar is removed in cases with maxillary asymmetry, and one mandibular and two maxillary premolars are removed in cases with mandibular asymmetry.[9]

Dental arch analysis

Orthodontists have long recognized the importance of arch form in treatment planning and restoring functional occlusion. Studies have reported that the dental arch represents a semi-ellipse, a parabola, a catenary curve, and other geometric forms.[12-18] Others argue that there is too much individual variation to identify a general arch template. Although these reports all differ in the specific geometry endorsed, they all agree that the ideal dental arch form is a symmetric shape.[19,20]

Extraction therapy has received criticism due to the belief that extraction leads to narrowing of the dental arch and a decrease in smile esthetics. [21] It has been suggested that the change in certain arch dimensions, including anterior arch width, may be influenced by pre-treatment Angle classification and also extraction decisions.[22-26] Studies vary in their description of exactly what these arch changes are. BeGole et al[23] showed that there was a significant increase in canine and premolar arch width during non-extraction treatment, but no such increase was seen in maxillary arches in cases where premolars were extracted. Luppanappornlarp and Johnston[24] reported that premolar extraction had no significant effect on intercanine width during treatment of severely crowded Class II patients. Other studies have shown a significant increase in intercanine and interpremolar width when

treating with extractions. Bishara et al[25] demonstrated a significantly greater increase in arch width at anterior arch positions and at the premolars when premolars were extracted during the treatment of Class I and Class II division 1 malocclusions than treatment without extractions. Kim and Gianelli[26] also reported a significantly greater arch width increase in extraction than in non-extraction groups. It has been reported, therefore, that the intercanine distance can decrease, stay the same, or increase during extraction treatment, as compared to non-extraction treatment.

A significant increase or decrease in intercanine width following extraction treatment results in a changed arch form. It is reasonable to speculate that a unilateral premolar extraction would cause arch form in that quadrant to respond differently than in the contralateral, non-extraction, quadrant. The difference between contralateral arch shape defines arch asymmetry, with the possible outcomes including both the apparent collapse[21] or widening[25,26] of the arch on the extraction side. The resulting anterior arch form may then be asymmetric despite the achievement of proper midline positioning and a corrected Class I canine. For the patient, this may result in asymmetric lateral overjet or an unaesthetic appearance of the teeth when smiling. There are few reports in the orthodontic literature discussing asymmetric extraction treatment plans and the effects of unilateral extractions on dental arch symmetry. The purpose of this study was to examine the post-treatment symmetry of arches that were treated with asymmetric (unilateral) extractions. The aim was to test the null hypothesis that treating asymmetric malocclusions with asymmetric extractions did not result in greater asymmetry of anterior arch form than other orthodontic treatments where the arches were treated symmetrically.

<center>Materials and Methods</center>

The records of patients previously treated at the Virginia Commonwealth University Department of Orthodontics were reviewed for inclusion in this study. Pre- and post-treatment study models were examined to ensure the following criteria were met: patients presented for treatment with a complete permanent dentition, no contralateral tooth size discrepancy was present (i.e. unilateral peg lateral), there was no noticeable occlusal wear, and the patients' treatment did not include orthognathic surgical intervention. Four study groups were created based on the treatment extraction patterns (Table I): non-extraction (control), asymmetric maxillary extraction treatment (one-bi), asymmetric mandibular extraction (three-bi), and bilateral maxillary and mandibular extractions (four-bi).

The control group patients did not have a pre-treatment molar asymmetry greater than one-half cusp and were not treated with extractions. The four-bi patients were also without a molar asymmetry greater than one-half cusp. Four premolars were extracted in these patients to correct an arch length discrepancy. The one-bi patients presented with a Class II subdivision malocclusion with the molar asymmetry being greater than one-half cusp. The asymmetry was determined to be in the maxilla as indicated by an upper dental midline deviation from the facial midline. One upper premolar was extracted on the Class

5

II side to achieve a Class I canine relationship. The three-bi patients also presented with a Class II subdivision malocclusion with the molar asymmetry being greater than one-half cusp. In these patients, the asymmetry was determined to be in the mandible as indicated by a lower dental midline deviation from the facial midline. Two contralateral upper premolars and a single lower premolar on the Class I side were extracted resulting in Class I canines bilaterally. Fifteen patients were chosen for each of the four groups. Post-treatment maxillary and mandibular casts of these 60 patients were examined and compared for intra-arch symmetry.

Dental arch landmarks and measurements

Two-dimensional occlusal images of the post-treatment arches were created by making a photocopy of the study model along with a millimeter ruler for scaling images (Fig 1) as recommended by BeGole et al.[23] The two dimensional occlusal image of each study cast was scanned into a computer and imported into a computer aided design (CAD) software program (DesignCAD 3000, Upperspace Corporation, Pryor, OK). Using the CAD software, the dental midline and distal interproximal contact of the first premolars were marked. The incisal midpoint of the central incisor (Tooth #1), the incisal midpoint of the lateral incisor (Tooth #2), the canine cusp tip (Tooth #3), and the buccal cusp tip of the first premolar (Tooth #4) were also plotted to allow the analysis of arch form (Fig 2). A line representing the arch length was drawn from the dental midline to the distal interproximal contact of the first premolar (arch length). The CAD program was used to

calculate the total area within the individual tooth landmarks and the arch length line (Fig 3). Lines, perpendicular from the arch length line, were drawn to each of the four tooth landmarks (Fig 4). Recorded arch dimensions included arch length distances (mm), distances from each tooth to the arch length line (mm), and the area between the arch length line and a line connecting the four tooth landmarks (mm^2) for each quadrant. The extraction side, right or left, was documented in arches treated with asymmetric extractions.

Statistical analyses

The 30 arches treated with unilateral extractions were evaluated for arch symmetry. Paired t-tests were used to compare arch dimensions between extraction and non-extraction sides of each arch. Specifically, the arch length, the distance of each tooth from the arch length reference (tooth position), and the area between the arch length line and a line connecting the tooth landmarks (area) were compared.

In order to determine whether asymmetric extractions resulted in asymmetric arch forms, the maxillary and mandibular arches from each of the four groups were divided into three categories: arches that were treated with asymmetric extractions (A), symmetrically treated arches opposing (occluding against) asymmetrically treated arches (SA), and symmetrically treated arches opposing symmetrically treated arches (SS) (Table II). The differences between the right and left sides for arch length, tooth position, and area were calculated for each of the subjects. The magnitude of the difference between sides was

recorded for each of the measurements. The mean of the differences were calculated for

each statistical category. MANOVA was used to determine significant differences in the

magnitude of arch asymmetry present among the three arch categories.

The mean values for the extraction and non-extraction sides for the unilateral extraction arches are listed in Table III. Significant differences in the location of the lateral incisor and canine cusp landmarks between the extraction and non-extraction sides in the asymmetrically treated arches were found (P < 0.001). The mean difference between sides for the location of the lateral incisor was -0.34 mm and was for the canine -0.53 mm. The negative values indicate that these landmarks were positioned closer to the palatal midline on the extraction side than on the non-extraction side. The arch length was longer by an average of 0.47 mm (P < 0.001) on the extraction side and the area was smaller by 5.24 mm^2 (P < 0.01).

There were no significant differences in any of the measures of arch symmetry among the three treatment groups. The differences in tooth position, arch length, and area between contralateral quadrants for each of the treatment groups are shown in Table IV.

9

Discussion

Choice of methods

The method used to evaluate arch symmetry is of special interest because an
adequate median reference plane must be defined in order to measure and compare
contralateral sides. The anatomy of the palate has been used successfully to establish
stable reference landmarks in longitudinal studies designed to quantify the change in
position of teeth during treatment.[27] The goal of the current study, however, was to
examine post-treatment arch symmetry without regard to specific pre-treatment dental
positions. Using the median palatal raphe as the absolute reference line assumes that this
skeletal landmark is centered within the dental arch. It has been documented, however,
that dental and skeletal asymmetries are often not related.[3,5,27-29] Asymmetries evaluated in
this manner may be dental or the skeletal reference plane may be oriented asymmetrically
itself. Shah and Joshi,[29] in 1978, evaluated skeletal asymmetries using posteroanterior
cephalometrics. Their sample group consisted of 43 subjects with normal occlusion. They
found on average that the total maxillary area was significantly larger on the right side.
The lateral maxillary region exhibited the greatest degree of asymmetry of all facial
components evaluated.

10

Studies have demonstrated the improper use of skeletal landmarks to quantify dental asymmetries. In 1994, de Araujo et al[2] used two skeletal techniques to quantify midline deviations to identify and measure dental asymmetry. The dental midline was evaluated relative to both the median palatal raphe on study models and to midline skeletal anatomy on frontal cephalometric radiographs. Frequency of dental midline deviation was found to be different using the two different landmarks. They concluded that the two median reference planes were not coincident. In fact, there were significantly more asymmetries found in the same sample when the median palatal raphe was used as the reference compared to radiographic landmarks. This finding brings into question which of the two skeletal landmarks was more accurate in the sample population, if either. Lundström,[30] in 1961, discussed how recordings of transverse distances from the median palatal raphe should be considered unreliable. The raphe line is largely asymmetric and, even if not noticeable, may be oblique or S-shaped. In 1968, Lear[31] demonstrated through his cast tracing technique that a symmetric arch whose contralateral dentition and palatal contours superimpose well on each other may have an asymmetric relationship to the median palatal raphe. He noted that, when referenced from the palatal raphe, the difference in transverse premolar position varied by as much as 4.4 mm in symmetric arches. Skeletal landmarks, specifically the median palatal raphe, were avoided in the current study to prevent measurement errors that could be potentially incorporated by using poor reference landmarks (Fig 5).

The distal interproximal contact of the first premolar was chosen as a landmark in the current study as it was the most distal common point in all arches, extraction and non-extraction. It is common practice for orthodontic studies to use the dental midline and the mesial interproximal contact of the first molar as landmarks to measure arch length. However, this study included arches in which premolars were extracted. In unilateral extraction arches, the most distal common reference point in the dental arch is the distal of the first, or only, premolar. Distal to this contact in non-extraction quadrants was the second premolar, while a permanent molar was the next tooth in an extraction quadrant. Using the distal contact of the first premolar provided a standardized reference point available for use in all quadrants (Fig 6).

Clinical implications

The dental arch refers to teeth and the shape they collectively form within the alveolus. The stability of each dental arch is largely dependent on both bony support as well as the soft tissue influences of the teeth. A well-established occlusion accounts for a third component of stability, and is the result of the proper interrelationship of two well coordinated dental arches. Poor intercuspation of opposing arches could potentially result from the unilateral collapse of a dental arch altered by an asymmetric extraction pattern (Fig 7). Lack of coordination could result in a tooth or teeth off the ideal line of occlusion. Theoretically, this tooth could then be without an opposing occlusal stop, be in premature contact, or fail to function properly in excursive movements.

Opponents of asymmetric extraction patterns argue that a well-established occlusion results from arch symmetry and Class I canines and molars. Alternative treatment plans for patients with subdivision malocclusions would be to distalize the upper molar on the Class II side or to take out four premolars and close spaces using asymmetric mechanics. Distalizing a unilateral Class II molar should theoretically be limited to cases where mesial drift of the molar is the etiology of the asymmetry, which studies say is not usually the case.[3,7] Using asymmetric mechanics to close spaces could introduce significant unwanted side effects, potentially including rotations of the entire arch and cants.[4,8-10,32] Unilateral extraction treatments have been shown, however, to treat asymmetric occlusions successfully without the introduction of a cant in the occlusal plane.[33] Additionally, it has been shown that Class II malocclusions have a significantly better occlusal success rate when treated with upper extractions alone than with upper and lower extractions.[34] Extending the application of this logic to treatment of a class II, division 1, subdivision case, a better occlusal result would be expected from a plan including asymmetric extraction, finishing the Class II side with a Class II molar.

A statistically significant arch asymmetry was detected in the asymmetric extraction arches. The lateral incisor and canine landmarks were positioned significantly closer toward the palatal midline by 0.34 mm and 0.53 mm, respectively, on the extraction side compared to the non-extraction side ($P < 0.001$). The arch length was 0.47 mm longer on the extraction side. This small, but statistically significant finding ($P < 0.001$), is expected as the curve of the arch flattens (Fig 8). The area was seen to be smaller on the extraction side by 5.24 mm ($P < 0.01$).

It has been reported that some degree of arch asymmetry frequently exists naturally in the dental arch. Asymmetries form early, with maxillary dental arch asymmetry seen in 62% of children in the full primary dentition.[35] Transverse asymmetry greater than 2.0 mm exists in the primary dentition in as many as 25% of all children.[36] The dental arch seems to compensate naturally for a developing dental asymmetry in the opposing arch. If asymmetry is seen in one arch, there is an increased likelihood that the opposing arch is asymmetric.[36,37] Dental asymmetry is also regularly seen in the permanent dentition, as previously discussed.[1-3,7-11] In a study of randomly selected orthodontic patients, it was reported that 84% of all the dental arches were made more symmetrical by orthodontic treatment.[27]

The benefit of asymmetric extractions is to successfully correct the occlusal asymmetry while avoiding the possible introduction of unwanted side effects. All 60 patients whose post-treatment models were examined in this study finished treatment successfully with a bilateral Class I canine relationship. A significant arch asymmetry was found in the patients treated with asymmetric extractions. Lateral incisor and canine positions were different between extraction and non-extraction sides. It should be noted, however, that the difference was small and can be considered clinically insignificant. Arch length and the area between the arch length line and the tooth landmarks were also significantly different between the extraction and non-extraction sides, but the magnitude of the difference was again very small when comparing them to the mean values between sides.

Hechter[27] reported that arch symmetry generally improved following orthodontic treatment. The goal of the current study was to determine if asymmetrically treated arches finish with similar symmetry as symmetrically treated arches. Experimental groups were divided based on the treatment method employed in each dental arch. Asymmetrically treated arches were categorized as one group. Because symmetry of the dental arch may be influenced by asymmetries in the opposing arch,[36, 37] the symmetrically treated arches were then sub-divided, taking into account the treatment of the opposing arch. There were no significant differences detected for any of the measures of arch symmetry among the 3 treatment groups (A, SA, SS).

Orthodontists frequently treat occlusal asymmetries. The correct diagnosis pinpointing the asymmetric arch is necessary to select the appropriate treatment. The Class II, division 1, subdivision malocclusion is common, and is most often a result of an incorrect dentoalveolar, not skeletal, position.[3,7] The unilateral removal of a tooth addresses the dental asymmetry and allows treatment of the malocclusion with symmetric mechanics, greatly reducing undesirable side-effects of asymmetric biomechanical techniques. This study showed that asymmetric extraction treatments successfully allow compensation for dental asymmetries and attainment of symmetric results, allowing for arch coordination and correction of occlusion.

Conclusions

The purpose of this study was to determine whether orthodontic treatments involving asymmetric extractions result in arches that are asymmetrically shaped. Some degree of dental asymmetry is commonly present in the primary dentition and the orthodontically untreated permanent dentition.[1-3,7-10,35-37] Orthodontic treatment, in general, has been shown to increase arch symmetry.[27] This study found that arches treated with asymmetric extractions finished with a small degree of asymmetry, with the lateral incisor and canine tooth positions being located more palatally on the extraction side. The magnitude of the asymmetry seen in the unilateral extraction arches, however, was not significantly greater than those seen in arches treated symmetrically, including orthodontically treated patients with no history of dental asymmetries. Some asymmetry is considered commonplace, and the goal to achieve absolute symmetry has been considered abnormal, unrealistic and unnecessary.[38-40] An asymmetric extraction plan is appropriate for the treatment of Class II, division 1, subdivision patients.

16
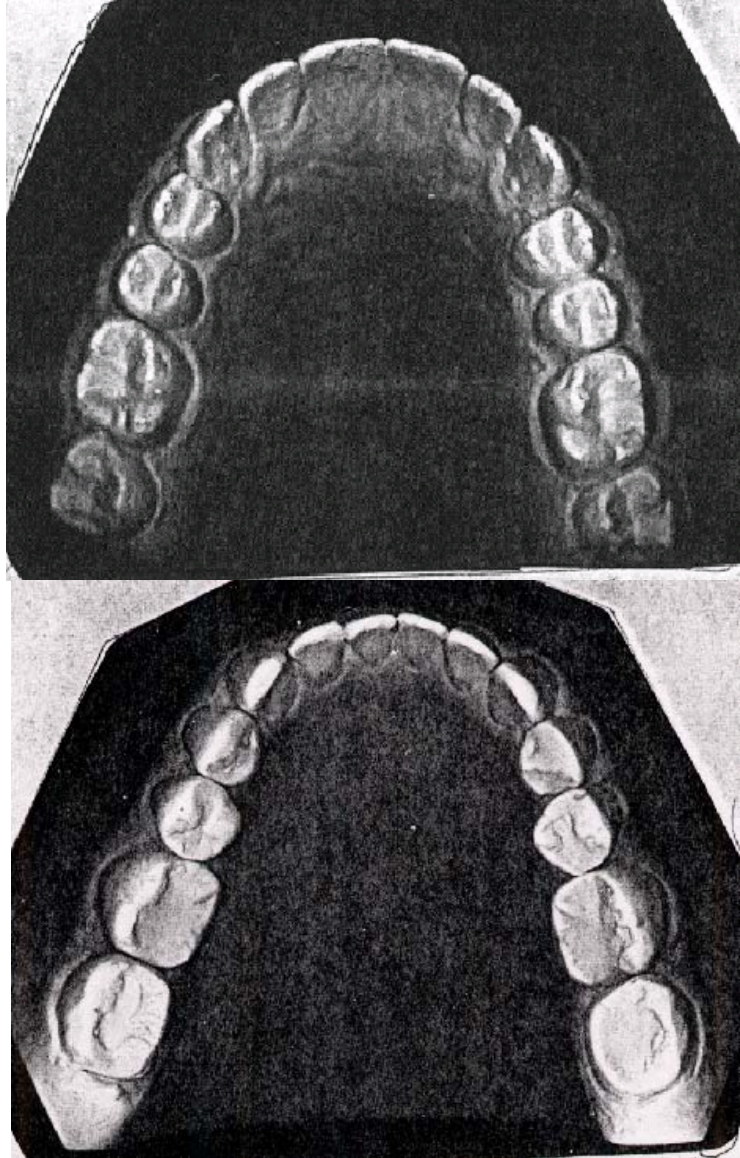
Fig 1. Occlusal images are scanned into the computer and imported into DesignCAD 3000 imaging software.

17
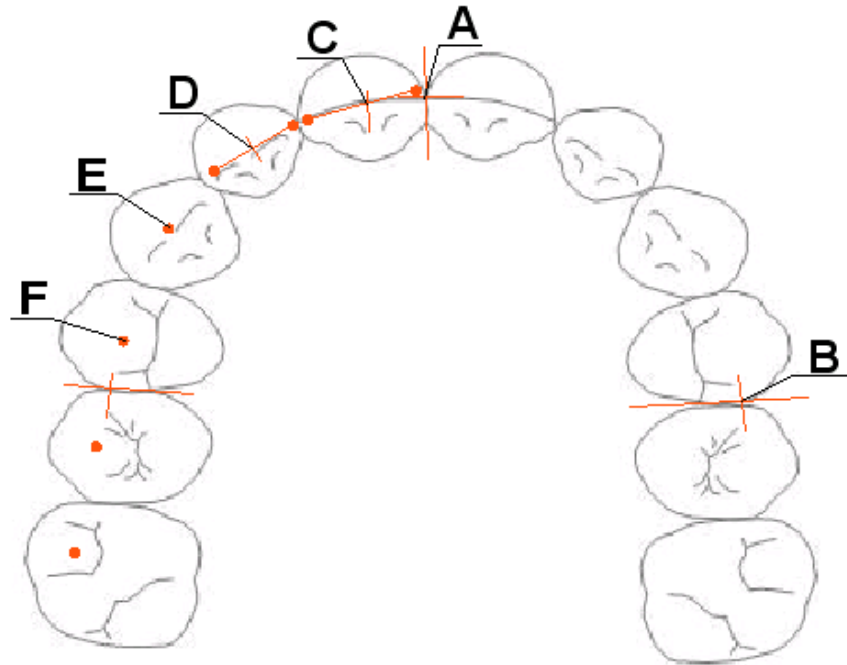
Fig 2. Diagram of dental landmarks identified in each quadrant. **A,** Dental midline.
B, Distal contact of first premolar. **C,** Incisal edge midpoint of central incisor.
D, Incisal midpoint of lateral. **E,** Canine cusp. **F,** First premolar buccal cusp.
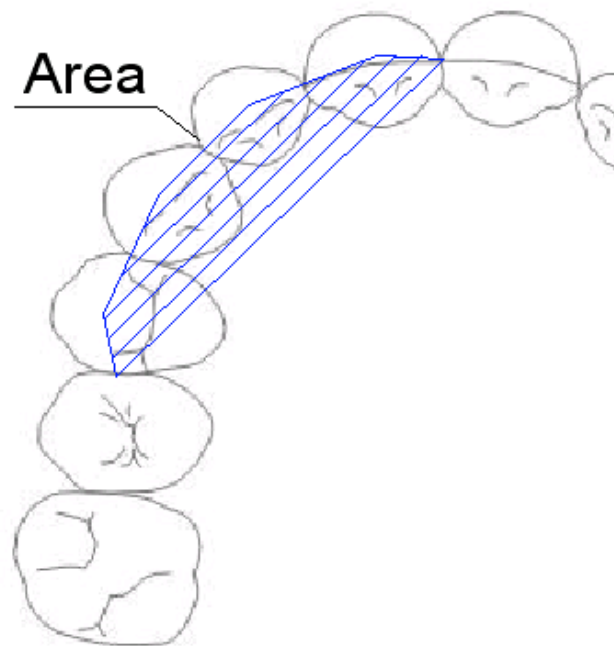
Fig 3. Arch area: The total area within the above identified landmarks (Arch Length line, central incisor midpoint, lateral incisor midpoint, canine cusp tip, first premolar buccal cusp tip, and distal contact of first premolar).

19

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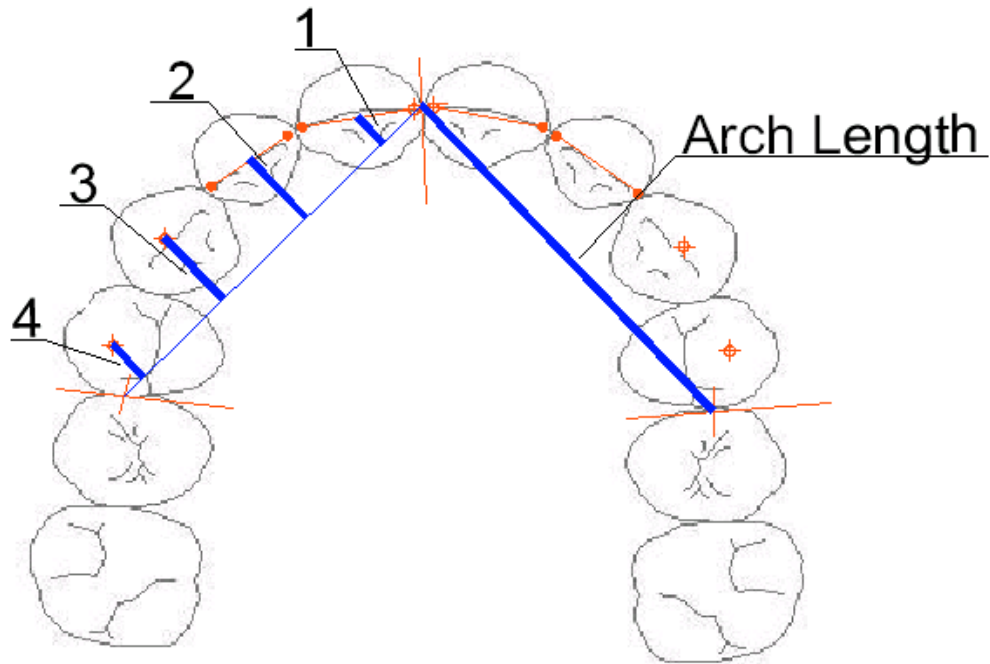
Fig 4. Linear measurements (mm):

Arch Length – Distance between dental midline and distal contact of
 first premolar.
1 – Perpendicular distance of the incisal midpoint of the central incisor
 to the arch length line.
2 – Perpendicular distance of the incisal midpoint of the lateral incisor
 to the arch length line.
3 – Perpendicular distance of the canine cusp to the arch length line.
4 – Perpendicular distance of the first premolar buccal cusp tip to the
 arch length line.

20

Fig 5. Improper use of the median palatal raphe as an arch symmetry reference. The above illustrations show the same symmetric dental arch. **A & B,** The mirror image of the upper left (red) quadrant is superimposed along the raphae. **A,** The median palatal raphe lies exactly on the midline. The superimposition demonstrates how the linear values from the raphae to dental landmarks would be accurate. **B,** The raphae is rotated within the dental arch only three degrees. When superimposed on the raphae, it is noticeable the values would be smaller for the upper left canine and premolar compared to the right. The values would indicate that this side has collapsed in toward the midline although the arch is perfectly symmetrical.
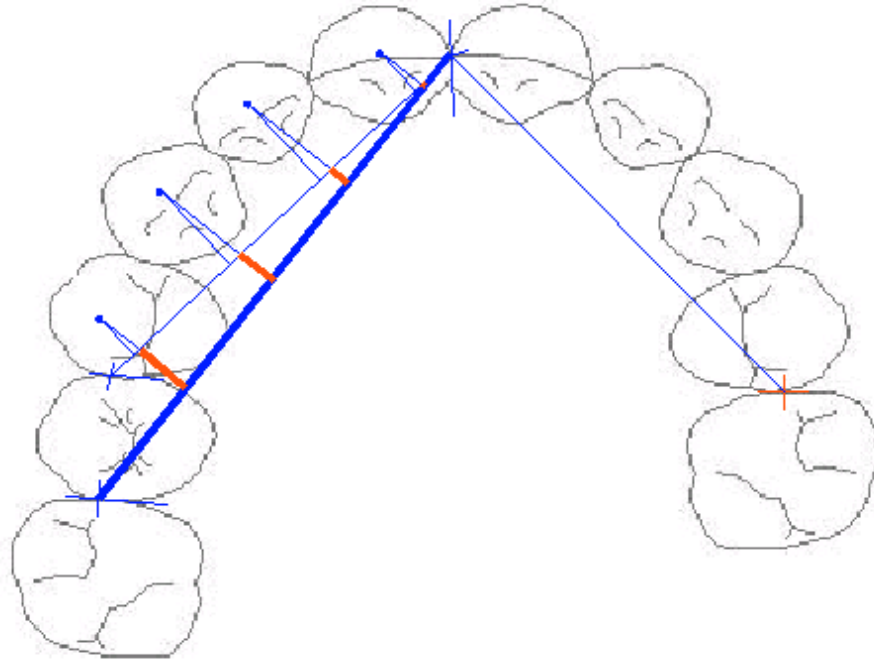
Fig 6. Use of the distal contact of the first premolar maintains a common reference between contralateral quadrants with different numbers of teeth. The above illustration is an arch which has had a unilateral extraction. The arch form is perfectly symmetrical. It is apparent that the two sides cannot be evaluated from the mesial contact of the first molar. The red lines on the non-extraction side represent the additional distance that would be recorded and interpreted by the statistics as a collapsing of the arch.
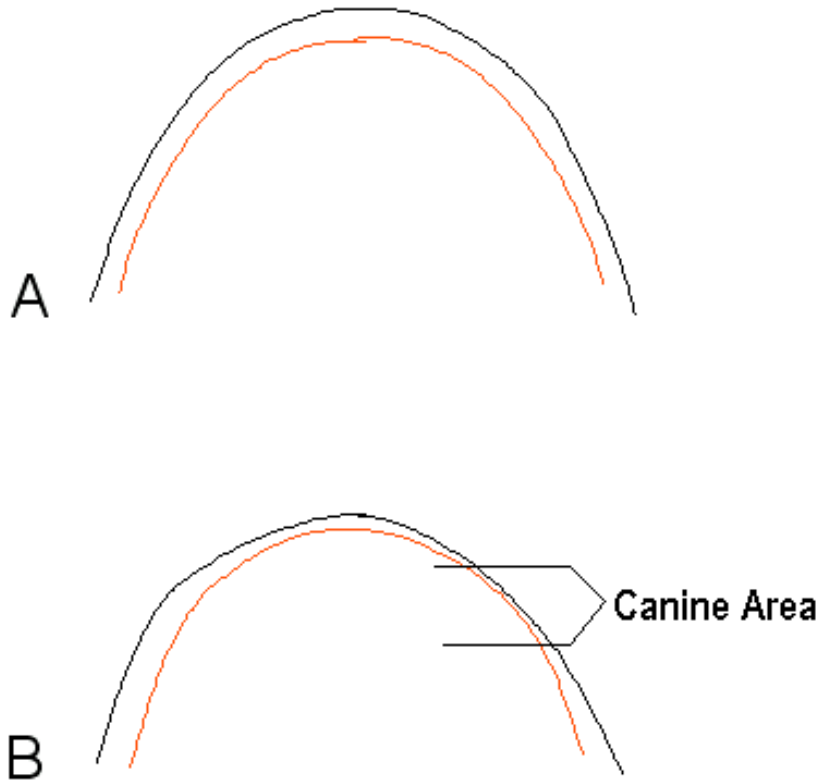
Fig 7. Relationship of arch asymmetry and arch coordination. **A,** The lines of occlusion of a maxillary (black) arch and its opposing mandibular arch in a patient whose upper and lower arches both demonstrate symmetric form. Notice how the distance between the buccal cusps and incisal edges of the opposing arches stays uniform, with the upper slightly outside the lower. **B,** The cusp tip of the upper canine approaches the line of occlusion of the lower arch when the arch asymmetrically collapses on that side. A lack of lateral overjet in the canine region could potentially result.

Fig 8. As the arch form flattens, or "caves in", the arch length gets longer. Dental arch quadrants treated with extractions were seen to have a flattened arch with the canine and lateral incisor being significantly closer to the arch length line than the contralateral quadrant treated without extractions (P < 0.001). In the absence of a contralateral tooth size discrepancy, the length of the arch perimeter from the dental midline to the distal contact of the first premolar should be equal on the extraction and non-extraction sides. **A.** The perimeters of the two arcs in this example are the same length. The arc on the right is more flat representing the flattening of the arch on the extraction side. **B.** The base of the arc, representing the arch length line, is longer on the arc that has flattened. The area (within the arc and its base) of the flattened "extraction" arc is 65.2% the size of the fuller "non-extraction" arc in this example.

24

Table I. Study groups

Group	Experimental Description	Arch	Arch Description	Extraction Pattern
Control	Symmetric	Maxillary	Symmetric	Non-extraction
		Mandibular	Symmetric	Non-extraction
One-bi	Asymmetric	Maxillary	Asymmetric	Unilateral Extraction
		Mandibular	Symmetric	Non-extraction
Three-bi	Asymmetric	Maxillary	Symmetric	Bilateral Extraction
		Mandibular	Asymmetric	Unilateral Extraction
Four-bi	Symmetric	Maxillary	Symmetric	Bilateral Extraction
		Mandibular	Symmetric	Bilateral Extraction

25

Table II. Arch categories for statistical comparison.

Group	Arch	Statistical Category
Control	Maxillary	SS
	Mandibular	SS
One-Bi	Maxillary	A
	Mandibular	SA
Three-bi	Maxillary	SA
	Mandibular	A
Four-bi	Maxillary	SS
	Mandibular	SS

26

Table III. Mean values of extraction and non-extraction quadrants of arches treated asymmetrically. Negative values for the difference of the means indicate that the tooth landmark on the extraction side was more toward the palatal midline. Negative mean values for arch length and area indicate that the extraction side had a shorter arch length or a smaller area, respectively.

	Mean Value (mm)		*Difference of Means (mm)*	*95% Confidence Limits of the Difference of the Mean (mm)*
	Extraction	*Non-extraction*		
Central	2.13	2.21	-0.08	-0.17 to 0.014
Lateral	4.20	4.54	-0.34*	-0.52 to -0.16
Canine	4.48	5.02	-0.53*	-0.81 to -0.26
Premolar	2.48	2.41	-0.07	-0.14 to 0.28
Arch Length	26.87	26.40	0.47*	0.21 to 0.73
Area (mm^2)	84.05	89.29	-5.24**	-9.01 to -1.47

*Statistically significant difference (P < 0.001)
**Statistically significant difference (P < 0.01)

27

Table IV. Mean differences between right and left tooth landmarks, arch length, and area by arch treatment group. MANOVA analysis shows no significant difference between the three groups for any of the evaluated arch characteristics.

Group	Central (mm)		Lateral (mm)		Canine (mm)		Premolar (mm)		Arch Length (mm)		Area (mm^2)	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
SS	0.188	0.16	0.348	0.32	0.573	0.45	0.426	0.35	0.499	0.36	0.782	0.67
SA	0.223	0.17	0.369	0.30	0.606	0.43	0.410	0.32	0.623	0.47	0.821	0.69
A	0.205	0.16	0.464	0.37	0.731	0.53	0.448	0.35	0.692	0.46	0.875	0.71
P-value	0.618		0.282		0.313		0.913		0.095		0.830	

28

References

References

1. Sheats RD, McGorray SP, Musmar Q, Wheeler TT, King GJ. Prevalence of orthodontic asymmetries. Semin Orthod 1998;4:138-45.

2. de Araujo TM, Wilhelm RS, Almeida MA. Skeletal and dental arch asymmetries in Class II division 1 subdivision malocclusions. J Clin Pediatr Dent 1994;18:181-5.

3. Janson GR, Metaxas A, Woodside DG, de Freitas MR, Pinzan A. Three-dimensional evaluation of skeletal and dental asymmetries in Class II subdivision malocclusions. Am J Orthod Dentofacial Orthop 2001;119:406-18.

4. Burstone CJ. Diagnosis and treatment planning of patients with asymmetries. Semin Orthod 1998;4:153-64.

5. Nanda R, Margolis MJ. Treatment strategies for midline discrepancies. Semin Orthod 1996;2:84-9.

6. Joondeph DR. Mysteries of asymmetries. Am J Orthod Dentofacial Orthop 2000;117:577-9.

7. Rose JM, Sadowsky C, BeGole EA, Moles R. Mandibular skeletal and dental asymmetry in Class II subdivision malocclusions. Am J Orthod Dentofacial Orthop 1994;105:489-95.

8. Shroff B, Siegel SM. Treatment of patients with asymmetries using asymmetric mechanics. Semin Orthod 1998;4:165-79.

9. Reballato J. Asymmetric extractions used in the treatment of patients with asymmetries. Semin Orthod 1998;4:180-8.

10. Lindauer SJ. Asymmetries: diagnosis and treatment. Semin Orthod 1998;4:133.

11. Lewis PD. The deviated midline. Am J Orthod 1976;70:601-16.

12. Black GV. Descriptive anatomy of the human teeth. 5th ed. Philadelphia: SS White Dental Mfg Co; 1907. p. 130-52.

13. Hawley CA. Determination of the normal arch and its application to orthodontia. Dental Cosmos 1905;47:541-52.

14. Angle EH. Treatment of malocclusions of teeth 7th ed. Philadelphia, 1907. SS White Dental Mfg Co; 1907.

15. Hellman M. Dimension vs. form in teeth and their bearing on the morphology of the dental arch. Int J Orthodontia 1919;5:615-51.

16. Chuck GC. Ideal arch form. Angle Orthod 1934;4:312-27.

17. Musich DR, Ackerman JL. The catenometer, a reliable device for estimating dental arch perimeter. Am J Orthod 1973;63:366-75.

18. Scott JH. The shape of dental arches. J Dent Res 1957;36:996-1003.

19. Currier, JH. A computerized geometric analysis of human dental arch form. Am J Orthod 1969;56:164-79.

20. Izard G. New Method for the determination of the normal arch by the function of the face. Int J Orthodontia 1927;13:582-95.

21. Witzig JW, Spahl RJ. The clinical management of basic maxillofacial orthopedic appliances. Vol 1. Mechanics. Littleton, Mass., 1987. PSG Publishing; 1-13.

22. Shapiro PA. Mandibular dental arch form and dimension. Am J Orthod 1974;66:58-70.

23. BeGole EA, Fox DL, Sadowsky C. Analysis of change in arch form with premolar expansion. Am J Orthod Dentofacial Orthop 1998;113:307-15.

24. Luppanapornlarp S, Johnston LE Jr. The effects of premolar extraction: a long term comparison of outcomes in "clear-cut" extraction and non-extraction Class II patients. Angle Orthod 1993; 64:257-72.

25. Bishara SE, Cummins DM, Zaher AR. Treatment and posttreatment change in patients with Class II, Division 1 malocclusion after extraction and nonextraction treatment. Am J Orthod Dentofacial Orthop 1997;111:18-27.

26. Kim E, Gianelly AA. Extraction vs. nonextraction: arch widths and smile esthetics. Angle Orthod 2003;73:354-58.

27. Hechter FJ. Symmetry and dental arch form of orthodontically treated patients. Dent J 1978;44:173-84.

28. Letzer GM, Kronman JH. A posteroanterior cephalometric evaluation of craniofacial asymmetry. Angle Orthod 1967;37:205-11.

29. Shah SM, Joshi MR. An assessment of asymmetry in the normal craniofacial complex. Angle Orthod 1978;48:141-8.

30. Lundström A. Some asymmetries of the dental arches, jaws, and skull, and their etiological significance. Am J Orthod 1961;47:81-106.

31. Lear CS. Symmetry analysis of the palate and maxillary dental arch. Angle Orthod 1968;38:56-62.

32. Shroff B, Lindauer SJ, Burstone CJ. Class II subdivision treatment with tip-back moments. Euro J Orthod 1999;19:93-101.

33. Janson G, Cruz KS, Woodside DG, Metaxas A, de Freitas MR, Henriques JF. Dentoskeletal treatment changes in Class II subdivision malocclusions in submentovertex and posteroanterior radiographs. Am J Orthod Dentofacial Orthop 2004;126:451-63.

34. Janson G, Brambilla A de C, Henriques JF, de Freitas MR, Neves LS. Class II treatment success rate in 2- and 4- premolar extraction protocols. Am J Orthod Dentofacial Orthop 2004;125:472-9.

35. Tsai HH. Variations among the primary maxillary dental arch forms using a polynominal equation model. J Clin Pediatr Dent 2003;27:267-70.

36. Maurice TJ, Kula K. Dental arch asymmetry in the mixed dentition. Angle Orthod 1998;68:37-44.

37. Kula K, Esmailnejad A, Hass A. Dental arch asymmetry in children with large overjets. Angle Orthod 1998;68:45-52.

38. Ferrario VF, Sforza C, Colombo A, Miani A, D'Addona A. Position and asymmetry in untreated dental arches. Int J Adult Orthodon Orthognath Surg 1993;8:277-85.

39. Gottlieb EL. A farewell to symmetry. J Clin Orthod 1993;27:357-58,360.

40. Pepe SH. Polynomial and catenary curve fits to human dental arches. J Dent Res 1975;54:1124-32.

VITA

Theodore W. Struhs was born in Denver, Colorado on May 23, 1974. He attended public schools in Arapahoe County, Colorado and graduated from Cherry Creek High School in 1992. He received a Bachelor of Science degree from Colorado State University in 1996 in Biology. He proceeded to Virginia Commonwealth University School of Dentistry and earned his Doctor of Dental Surgery degree in 2003. He is currently enrolled in the postgraduate orthodontics specialty program at Virginia Commonwealth University and will earn a certificate in the specialty of orthodontics and a Master of Science. He plans to return to Denver, Colorado upon graduation and enter into private practice. He is married and has two sons.