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Arch-width changes in extraction vs nonextraction treatments in matched Class I borderline malocclusions

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Abstract: INTRODUCTION: The aims of this study were to identify a sample of borderline Class I extraction and nonextraction patients and to investigate posttreatment changes in arch-width and perimeter measurements. METHODS: A parent sample of 580 Class I patients was subjected to discriminant analysis, and a borderline subsample of 62 patients, 31 treated with extraction of 4 first premolars and 31 treated without extractions, was obtained. The patients' plaster casts were digitally scanned, and the maxillary and mandibular intercanine and intermolar widths and perimeters were assessed. RESULTS: The extraction group showed increases in maxillary and mandibular intercanine widths (P <0.001) and decreases in mandibular intermolar width and in maxillary and mandibular perimeters (P <0.001). The nonextraction group showed increases in all 4 arch-width measurements (P 0.003), whereas the maxillary and mandibular perimeters were maintained. The posttreatment differences between the 2 groups showed significant differences in the maxillary (P <0.001) and mandibular intermolar widths (P <0.001). Also, the comparison of the arch perimeters between the 2 treatment groups showed adjusted differences of -8.51 mm (P <0.001) and -8.44 mm (P <0.001) for the maxillary and mandibular arches, respectively. The intercanine widths showed no changes between the 2 treatment groups. CONCLUSIONS: Borderline Class I patients treated with extraction of 4 first premolars had decreased maxillary and mandibular intermolar and perimeter measurements compared with nonextraction patients. The maxillary and mandibular intercanine widths showed no significant difference between the 2 treatment groups.

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INTRODUCTION

In treatment planning a case an experienced orthodontist reaches rather clearly a decision in regards to the extraction or non-extraction treatment modality. This usually occurs in clear-cut cases where the decision is easy to make; however, there is a spectrum of patients that can be treated either way forcing the orthodontist to deliberate between different treatment options. These borderline patients require a careful estimate of the possible impact the treatment choice might have on the facial profile,[1-5] the smile aesthetics,[6,7] the stability,[8] and a series of other factors that the orthodontist considers in favouring one treatment option over another.

Often, concerns arise around the impact of the extractions on soft-tissue aesthetics. Mc Namara et al. reported a direct link between arch-width and smile aesthetics,[9] while Zachrisson et al. indicated that the inclination of the canines and premolars are a key factor for a full smile.[10] Recently, changes in buccal corridors have been compared after extraction and non-extraction treatment.[11,12] While a minimal buccal corridor is favorable,[13] extraction therapy does not necessarily lead to a smaller arch-width than non-extraction therapy.[14-17] Some authors[6,11,16,18,19] report widening of the maxillary intercanine width in the extraction cases, while Germec-Cakan et al.[15] found no significant change. A slight increase regarding mandibular intercanine width has been reported in extraction cases.[6,14-17] On the other hand, the intermolar width seems to decrease during extraction treatment in both jaws.[8,15-21]

In retrospective surveys that compare outcomes of treatment modalities all groups must be equally matched according to the diagnostic variables that the clinician uses to establish a treatment decision. In orthodontics these variables are: the measurements of the cephalometric analysis and the dental casts along with the age and sex of the patient. However, the majority of the aforementioned studies assessed treatment changes either in clear-cut or in arbitrarily defined borderline cases in regards to the extraction modality. Furthermore, several studies included different types of malocclusion in the same treatment group.[6,14,20] Inevitably, the results of those studies were often contaminated with susceptibility bias, which is defined as the difference in prognostic expectations due to pre-existing differences at the onset of treatment. Such patient's features which lead a clinician to a specific treatment decision are called confounding variables.[22] Discriminant analysis is a statistical multivariate technique, which deals concurrently with a large number of confounding variables.

In current orthodontic research it has been proven to mimic the decision-making process of an experienced orthodontist.[23] This analysis can predict group membership, as in extraction or non-extraction treatment. It can also identify a spectrum of borderline cases which cannot be classified to any group, and that consequently could be treated either way.[8,23,24] The use of discriminant analysis ensures that all patients who comprise the borderline group are equally susceptible to both treatment modalities; therefore, susceptibility bias is eliminated.

The aim of this study was to identify a bias-free sample of extraction and non-extraction Class I patients and to compare their transverse maxillary and mandibular arch-width and perimeter changes.

MATERIALS AND METHODS

A parent sample of 580 patients, 349 female and 231 male, was collected from the graduate orthodontic clinic of the XXX and five different private orthodontic practices in XXX. Of these patients, 427 received non-extraction treatment, whereas 153 were treated by extraction of the first four bicuspids.

All patients were Caucasian males and females with a full complement of teeth (excluding the third molars) and a Class I dental and skeletal malocclusion. They had no history of any cleft, dentofacial deformity, or syndrome, and they also had never received any previous orthodontic or orthognathic surgery treatment. All patients were treated with preadjusted edgewise appliances in both arches, without the use of any extraoral or temporary anchorage device. The patients' diagnostic records included an initial lateral cephalometric radiograph taken at the natural head position, a panoramic radiograph and initial and final dental casts. All cephalometric analyses were performed using Viewbox 4.0.1.7 (dHAL Software, Kifissia, Greece). The research protocol was approved by the Ethics committee of of the University of XXX.

To eliminate proficiency and selection bias the parent sample was reduced to a borderline sample by means of a stepwise discriminant analysis. The confounding variables used in the discriminant analysis were 26 cephalometric and 6 plaster cast measurements along with the two variables of gender and age. This approach allowed an accurate representation of the most important dental, skeletal and soft tissue traits that have an impact on an orthodontist's treatment decision.[23] A discriminant score was calculated for each patient ranging from –3.5 to +3.07. While patients with positive scores were most likely treated without extractions, patients with negative scores received extraction treatment. The unclassified cases around the cut-off point, which was determined at 0, were identified as the borderline cases and thereby composed the borderline spectrum of patients.

Then, a power test was calculated to assess the sample size required. The power test resulted in a sample size of 64 subjects needed to detect a clinically significant difference of 2.15 units with a common standard deviation of 3 units, assuming a 2-sided type I error of 5% and a power of 80%. Finally, a group of 62 Class I borderline patients 38 female and 24 male, who exhibited a similar degree of dental and skeletal discrepancy at the onset of treatment was identified. Of the patients, 31 were treated non-extraction whereas 31 were treated by extraction of the four first premolars. Of the non-extraction patients, 17 (54.84%) were female whereas 14

(45.16%) were male. Of the extraction patients, 21 (67.74%) were female and 10 (32.26%) were male. The mean age was 14.0 years (standard deviation (SD)=5.44) for the non-extraction and 13.0 (SD=3.27) for the extraction group respectively.

Next, in order to measure the maxillary and mandibular intercanine and intermolar widths and arch perimeters, the pre- and post- treatment plaster dental casts of the borderline patients were utilized. All dental casts were scanned with a digital scanner (3Shape R700, Copenhagen, DK) and the measurements were performed with Ortho Analyzer software (3Shape 2013-1, Copenhagen, DK). The intercanine width was assessed as the distance between the cusp tips of the maxillary and mandibular right and left canines, while the intermolar width was assessed as the distance between the mesiobuccal cusp tips of the right and left first molars in the maxillary and mandibular arches (Fig 1).

Additionally, in order to assess more accurately the arch perimeter we created a constructed occlusal plane by projecting 3 points above the actual occlusal plane. These projected points that defined the constructed occlusal plane were derived from: a point at the incisal tip of the right central incisor; a point at the mesial buccal cusp of the right first molar; and a point at the mesial buccal cusp of the left first molar for the maxillary and for the mandibular arch respectively. Then a specific point from each individual tooth up to the first molars (12 teeth) was projected on the constructed occlusal plane as follows: a point at the middle of the incisal edge of the four anterior incisors; a point at each buccal cusp of the first and second premolars; and a point at the distobuccal tip of the first molar. Next, the projected points were connected and formed the perimeter curves of each dental arch for the maxilla and the mandible (Fig 2).

To assess the intra- and intergroup differences in transverse arch-changes descriptive and inferential statistics were performed. The mean differences that each treatment group experienced from pretreatment to posttreatment were also compared using independent sample t-tests. Additionally, paired t-tests were calculated to assess the differences between pre- and post- treatment measurements for the two treatment groups. Since the dependent variables were likely to be correlated multivariate regression analysis was used to adjust the p-values for multiple comparisons using F-tests. The significance level was predetermined at 5%.

All measurements were performed by a single examiner (Principal investigator: XX) Additionally, evaluations were performed for both random and systematic errors of the method. To assess intra examiner repeatability, with a table of random numbers, 20 cases were selected -10 from each group- and were re-evaluated three weeks later by the same investigator (XX). Also, to assess inter-examiner agreement, 20 cases -10 extraction and 10 non-extraction- were randomly selected and the principal investigator was evaluated against another examiner (XX). This examiner was a member of the XXX Board of Orthodontics.

The intraclass correlation coefficient (ICC) based on the variance components from a one-way ANOVA was used. The results showed excellent agreement: ICC: 0.99; 95% CI, 0.99, 0.99 for intra- and ICC: 0.98; 95% CI, 0.95, 0.99 for inter- examiner agreement. Statistical analysis of the present study was carried out using the SPSS software (version 19.0;IBM, Armonk, NY).

RESULTS

The descriptive characteristics of the two groups of patients are listed in Table1. The p-values (t-test for independent samples) of the borderline sample measurements showed no statistically significant differences between the extraction and non-extraction patients at the onset of treatment. This finding was further confirmed by the P-value for pre-treatment differences in all outcomes that was 0.321.

Comparing pre- and posttreatment values in the extraction group, a significant increase of 1.90 mm (95% CI, 1.21, 2.59; $p<0.001$) in the maxillary and a 1.40 mm (95% CI, 0.71, 2.10; $p<0.001$) increase in the mandibular intercanine width was found. In contrast, the mandibular intermolar width decreased significantly by -1.72 mm (95% CI, -2.54, -0.90; $p<0.001$), while the maxillary intermolar width decreased slightly but not significantly by -0.69 mm (95% CI, -1.44, -0.06; p=0.07). The maxillary arch perimeter was decreased from 93.34 mm to 84.42 mm (mean diff. -8.92; 95%CI, -11.05, -6.78, p<0.001). Also, the mandibular arch perimeter decreased significantly from 80.21 to 72.47 mm (mean diff. -7.74; 95% CI, -9.89, -5.58; p<0.001).

In the non-extraction group the intercanine width increased significantly; 1.63 mm (95% CI, 0.94, 2.32; p<0.001) for the maxillary and 1.20 mm (95% CI, 0.50, 1.89; p=0.001) for the mandibular arch respectively. Likewise, maxillary and mandibular intermolar widths showed a significant increase of 1.57 mm (95% CI, 0.82, 2.32; p<0.001) and 1.28 mm (95% CI, 0.47, 2.10), respectively. However, the pre- and posttreatment arch perimeter values in the non-extraction group revealed no significant changes.

Taking into consideration the mean intragroup differences of all the variables simultaneously the F-test revealed a statistically significant change (Overall p-value <0.001) between pre and posttreatment for the extraction and non-extraction patients. All intragroup differences are listed in Table 2.

The differences of the mean change values for the maxillary and mandibular intercanine widths did not reveal any statistically significant difference. Contrariwise, the differences of the mean change values for the maxillary (Adj. mean dif.: -2.66; 95% CI, -3.68, -1.65, p<0.001) and mandibular (Adj. mean diff.: -3.42; 95% CI, -4.52, -2.32, p<0.001) intermolar widths was statistically significant. The comparison of the arch -perimeters between the 2 treatment groups revealed an adjusted difference of -8.51 mm (95% CI, -11.62, -5.40, p<0.001) and -8.44 mm (95% CI, -11.47, -5.41, p<0.001) for the maxillary and the mandibular arch respectively. However, the overall P-value between the mean changes of the 2 treatment groups was statistically significant (Overall p-value <0.001) (Table 3). All intra- and intergroup changes can be seen in Figure 3.

DISCUSSION

The findings of this retrospective survey revealed significant dental arch-width and perimeter changes as a result of orthodontic treatment. Arch-width changes have also been reported in several investigations as a result of extraction and non-extraction orthodontic treatment.[6,8,11,12,14-21] Several studies have assessed those changes but most of them suffer from susceptibility or selection bias.[6,14,20,18,21] It becomes apparent though, that if the initial populations for either treatment differ, any assumption about the impact of the treatment on various parameters is arbitrary.[13,25]

To overcome this problem and remove the aforementioned susceptibility bias in this research investigation a discriminant analysis was used to identify a borderline sample. Subsequently, the borderline sample that was obtained, ensured that all patients exhibited similar dental and skeletal parameters at the onset of treatment, hence any differences that were detected at the end could be reliably attributed to the chosen treatment itself rather than to pre-existing differences.[5,8,23,24,26,27] Furthermore, all the dental arch-width and perimeter parameters of both treatment groups presented no statistically significant differences at the onset of treatment; therefore, the borderline sample was appropriately identified.

Still, different ways of measuring dental arch-widths are suggested in the literature. Some authors measured the distance between defined teeth,[6,14-17] as in the present study, while other authors attempted to measure arch widths independently of specific teeth by utilizing two defined points on a virtual dental arch,[6] or even by superimposing on specific palatal soft tissue structures.[11,12] The latter methods might assess better changes in arch widths, particularly in treatments with anterio-posterior tooth movements, as in space closure. However, these methods depend on stable superimposition points. The palate's rugae could serve as reference points however the reproducibility might still be questionable and in any case this approach is not applicable in the mandible. Alternatively, the insertion of metal implants could provide adequate superimposition points. Since measurements between the dental cusp tips reflect the dental arch, as seen during a smile, this method was the one chosen in the present study.

Perimeter measurements were obtained by using a constructed occlusal plane. By using the constructed occlusal plane, any vertical discrepancies between the teeth, which could possibly lead to a misrepresentation of the actual dental arch perimeter, was eliminated. Therefore, the measured perimeter curves were not an assessment of tooth arch discrepancy but rather an appraisal of a 2-dimensional projection of the dental arches.

In the present research investigation significant widening of the maxillary intercanine width of 1.90 mm occurred in the extraction group, thus being in agreement with the findings reported by other authors,[6,11,16,18,19] but in disagreement with the reports of Germec-Cakan et al.[15] Likewise, the mandibular intercanine width increased significantly in the extraction group in accordance with the findings of most studies.[6,14-17] The intercanine width increase in both jaws can possibly be explained by the distalisation of the canines in a wider part of the dental arch during the phase of cuspid retraction.

A slight but statistically not significant decrease of -0.69 mm was noted in the maxillary intermolar width in the extraction cases. This measurement also proved to be stable in the extraction patients in the studies conducted by Aksu et al.[16] and Meyer et al.,[11] and decreased in the reports by Zachrisson and Germec_Cacan et al.[6,15] A significant decrease of -1.72 mm was revealed in the mandibular intermolar width, in rapport with other authors.[6,8,15-21] The narrowing of the mandibular intermolar width during extraction treatment, could possibly be attributed to the anterior movement of the mandibular molars during space closure in order to achieve a Class I relationship after the elimination of anterior crowding.

However, in the non-extraction group all arch-width parameters increased significantly. This probably occurred due to the lack of space for addressing the moderate crowding that these borderline cases presented. Several research studies that examined clear-cut non-extraction cases did not report any significant arch-width changes.[6,16-18] The different results are probably due to the fact that the clear-cut non-extraction cases do not require any amount of expansion to address crowding. A stable intercanine but a decreased intermolar width was reported by

Germec-Cakan et al[15] in the non-extraction cases that were treated though with air-rotor stripping.

Despite the significant increase of the maxillary and mandibular intercanine widths in both treatment groups, no significant changes were found when the 2 groups were compared. Other authors report similar results after the comparison of the intercanine widths between extraction and non extraction patients.[6,15,16] Our findings indicate, that in borderline cases the choice whether to extract or not has no impact on the intercanine width for both the maxillary and mandibular arches.

In contrast to intercanine widths, the present borderline sample exhibited significant differences between treatment modalities regarding intermolar width changes. The adjusted difference of -2.66 mm and -3.42 mm for maxillary and mandibular intermolar width respectively, indicated smaller arch-width in the extraction compared to the non-extraction treatment. These findings are also supported by other investigators and can be attributed to the forward movement of the first molars in the extraction cases after tooth-arch discrepancy problems at the anterior part of the dentition were addressed.[6,16,17] Conversely, Germec-Cakan et al.[15] reported this difference between extraction and non-extraction cases only in the mandibular intermolar width.

Despite the moderate posttreatment increase in arch-width, the present non-extraction sample has shown no significant differences for the maxillary and mandibular arch perimeters, which is in agreement with the borderline sample investigated by Germec-Cakan et al.[15] This can be explained by the fact that borderline cases present just a moderate amount of crowding and can subsequently be treated without significant perimeter enlargement. In contrast extraction cases showed a significant decrease in arch perimeter, which is an obvious occurrence due to the removal of dental substance, as long as the dental arches do not present severe crowding.

Buccal corridor dimensions are considered an important smile feature. A broad smile with small buccal corridors is considered to be aesthetically more pleasant than a narrow smile with large buccal corridors when judged by laypersons.[13,25] The buccal corridors are directly associated to the arch form and width changes which result after orthodontic treatment. Several studies report[13,7] no differences in smile aesthetics between extraction and non-extraction treatment.[6,11] In our study when all 6 measurements were simultaneously considered significant changes were revealed between the two different groups of patients. The findings of this research study suggest that in regards to the extraction vs non-extraction modality, treatment choice has a definitive impact on the transverse dental arch dimensions. However, the impact of these transverse dental arch changes on the buccal corridors and subsequently on smile aisthetics is still an issue, which should be further investigated.

CONCLUSIONS

1. Discriminant analysis allowed identification of a bias-free Class I borderline sample and ensured appropriate matching of the extraction and non-extraction patients.
2. In the extraction group, maxillary and mandibular intercanine width increased, whereas maxillary intermolar width showed no significant change and mandibular intermolar width decreased.
3. In the non-extraction group a significant increase of all arch-width measurements occurred, while the maxillary and mandibular perimeter dimensions were maintained.
4. Extraction treatment led to decreased maxillary and mandibular intermolar and perimeter measurements when compared with non-extraction treatment. The maxillary and mandibular intercanine widths showed no significant difference between the two treatment groups.

Figure legends

Figure 1: Maxillary and mandibular intercanine and intermolar width measurements in an extraction case. A: Pretreatment B: Posttreatment

Figure 2: Pretreatment (A) and posttreatment (B) mandibular perimeter measurements on the constructed occlusal plane in a non-extraction case.

Figure 3: Comparisons between pre and post treatment measurements in the extraction ( ) and non-extraction (. . . .) groups.

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Table 1. Descriptive characteristics of the 62 borderline patients.

Characteristic	Extraction (N = 31) Mean ± SD	Non-extraction (N = 31) Mean ± SD	P-value
Maxillary Intercanine width (mm)			
Pre-treatment	33.32 ± 2.62	33.63 ± 1.87	0.602
Post-treatment	35.22 ± 1.89	35.25 ± 1.22	0.930
Mandibular Intercanine width (mm)			
Pre-treatment	25.64 ± 2.56	25.69 ± 1.79	0.923
Post-treatment	27.04 ± 1.27	26.89 ± 1.11	0.619
Maxillary inter molar width (mm)			
Pre-treatment	49.01 ± 3.50	50.51 ± 2.40	0.056
Post-treatment	48.32 ± 2.44	52.07 ± 1.94	0.000
Mandibular inter molar width (mm)			
Pre-treatment	43.11 ± 3.78	44.14 ± 2.61	0.219
Post-treatment	41.39 ± 2.61	45.42 ± 2.05	0.000
Maxillary arch perimeter (mm)			
Pre-treatment	93.34 ± 5.54	93.09 ± 4.22	0.847
Post-treatment	84.42 ± 6.71	92.75 ± 5.82	0.000
Mandibular arch perimeter (mm)			
Pre-treatment	80.20 ± 5.36	81.46 ± 5.70	0.378
Post-treatment	72.47 ± 6.92	81.62 ± 5.80	0.000
Age at baseline (yr)*	13.0 (± 3.27)	14.0 (± 5.44)	0.474
Gender			0.297
Men (%)	10 (32.26)	14 (45.16)	
Women (%)	21 (67.74)	17 (54.84)	

*Median (IQR)

**P-value for pre-treatment differences in all outcomes = 0.321

Table 2. Differences between post- and pre-treatment measurements.

Variable	Pre-mean	Post-mean	Mean diff.	(95% CI)	P-value*	Overall P-value**
Extraction (N = 31)						<0.001
Maxillary Intercanine width (mm)	33.32	35.22	1.90	(1.21, 2.59)	<0.001	
Mandibular Intercanine width (mm)	25.64	27.04	1.40	(0.71, 2.10)	<0.001	
Maxillary inter molar width (mm)	49.01	48.32	-0.69	(-1.44, 0.06)	0.070	
Mandibular inter molar width (mm)	43.11	41.39	-1.72	(-2.54, -0.90)	<0.001	
Maxillary arch perimeter (mm)	93.34	84.42	-8.92	(-11.05, -6.78)	<0.001	
Mandibular arch perimeter (mm)	80.21	72.47	-7.74	(-9.89, -5.58)	<0.001	
Non-extraction (N = 31)						<0.001
Maxillary Intercanine width (mm)	33.63	35.25	1.63	(0.94, 2.32)	<0.001	
Mandibular Intercanine width (mm)	25.69	26.89	1.20	(0.50, 1.89)	0.001	
Maxillary inter molar width (mm)	50.51	52.07	1.57	(0.82, 2.32)	<0.001	
Mandibular inter molar width (mm)	44.14	45.42	1.28	(0.47, 2.10)	0.003	
Maxillary arch perimeter (mm)	93.09	92.75	-0.34	(-2.48, 1.79)	0.750	

Mandibular arch perimeter (mm)	81.46	81.62	0.15	(-2.00, 2.31)	0.884

* Compares the difference between pre- and post-treatment measurements by using a t-test.
** Tests whether all differences equal zero simultaneously by using a F-test.

Table 3. Comparison of intragroup differences between the extraction and the non-extraction groups

Difference between pre- and post-treatment meas.	**Extraction (95%CI)**	**Non-extraction (95%CI)**	**Adj. Difference* (95%CI)**	**P-value**	**Overall P-value****
					<0.001
Maxillary Intercanine width (mm)	1.90 (1.21, 2.59)	1.63 (0.94, 2.32)	0.09 (-0.91, 1.10)	0.852	
Mandibular Intercanine width (mm)	1.40 (0.71, 2.10)	1.20 (0.50, 1.89)	0.05 (-0.96, 1.06)	0.920	
Maxillary inter molar width (mm)	-0.69 (-1.44, 0.06)	1.57 (0.82, 2.32)	-2.66 (-3.68, -1.65)	<0.001	
Mandibular inter molar width (mm)	-1.72 (-2.54, -0.90)	1.28 (0.47, 2.10)	-3.42 (-4.52, -2.32)	<0.001	
Maxillary arch perimeter (mm)	-8.92 (-11.05, -6.78)	-0.34 (-2.48, 1.79)	-8.51 (-11.62, -5.40)	<0.001	
Mandibular arch perimeter (mm)	-7.74 (-9.89, -5.58)	0.15 (-2.00, 2.31)	-8.44 (-11.47, -5.41)	<0.001	

* Adjusted for baseline age and sex.

** Tests whether all differences between treatment groups equal zero by using a F-test.

Figure 1

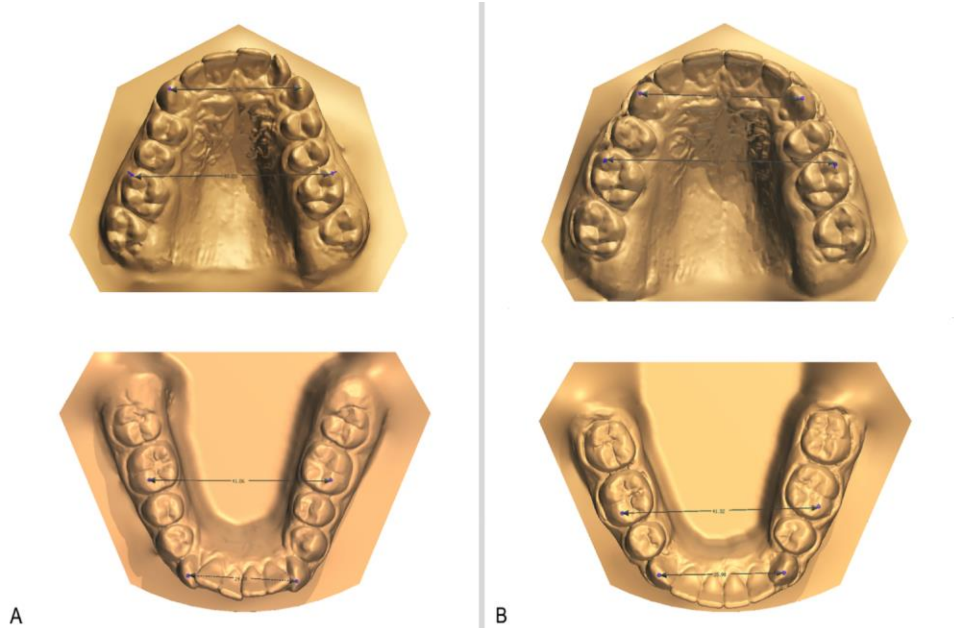


Figure 2

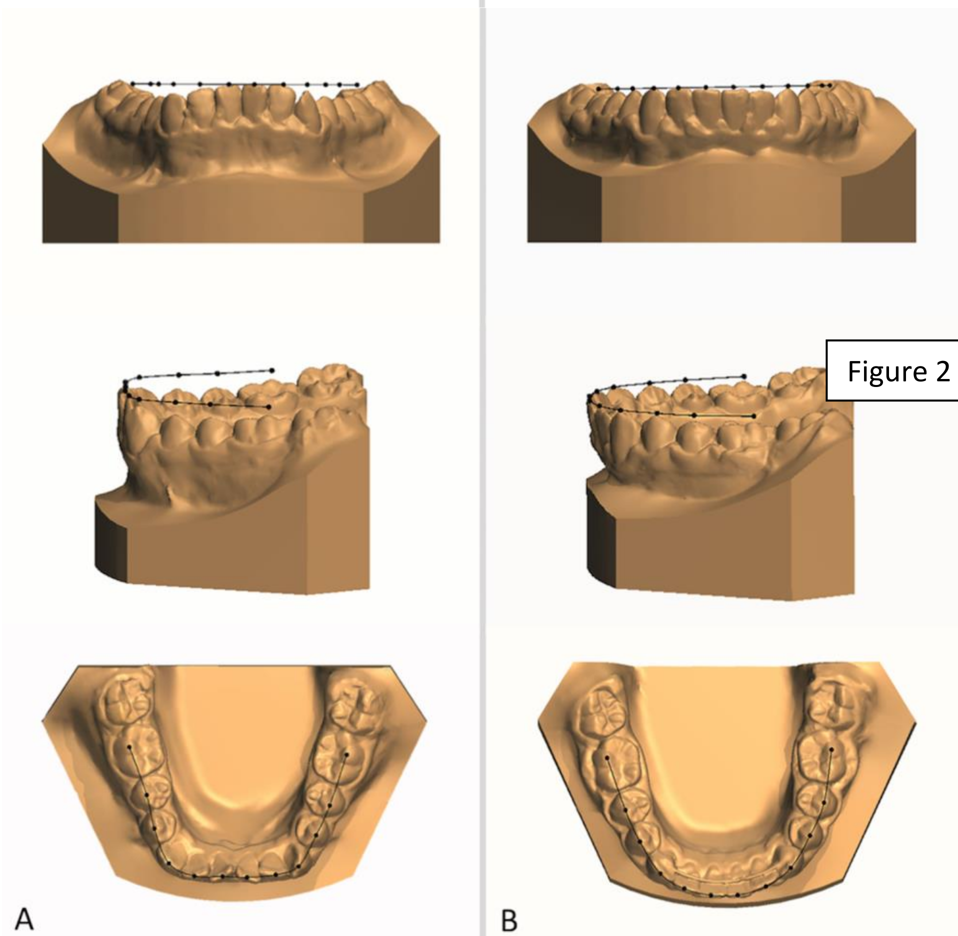
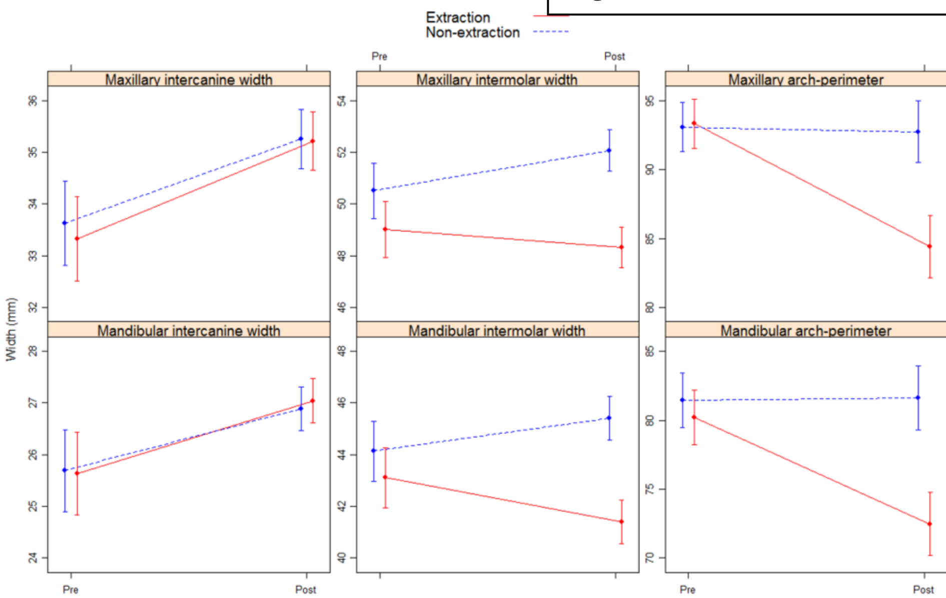


Figure 3



Extraction
Non-extraction
Maxillary intercanine width
Maxillary intermolar width
Maxillary arch-perimeter
Mandibular intercanine width
Mandibular intermolar width
Mandibular arch-perimeter
Width (mm)
Pre
Post