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ΤΜΗΜΑ ΟΔΟΝΤΙΑΤΡΙΚΗΣ

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CRANIOFACIAL GROWTH COVARIES WEAKLY WITH INITIAL SHAPE IN 12-YEAR OLD CHILDREN

Αλέξιος Θ. Κατσαδούρης

ΑΘΗΝΑ 2016

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Τριμελής Επιτροπή για την αξιολόγηση της Μεταπτυχιακής Διπλωματικής Εργασίας:

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Ευχαριστίες

Ολοκληρώνοντας το δεύτερο κύκλο σπουδών θέλω να ευχαριστήσω ιδιαίτερα τον Αναπληρωτή Καθηγητή του Εργαστηρίου της Ορθοδοντικής του Πανεπιστημίου Αθηνών και επιβλέποντά μου στο μεταπτυχιακό πρόγραμμα κ. Δημήτριο Χαλαζωνίτη για την καθοδήγηση και την ουσιαστική συμβολή του στην εκπαίδευσή μου. Τον ευχαριστώ επίσης για την εμπιστοσύνη και τη στήριξή του σε κάθε επιστημονικό μου βήμα. Θα ήθελα να τον ευχαριστήσω τόσο για τη βοήθειά του στην επιλογή του θέματος όσο και για την καθοδήγησή του στην ολοκλήρωση και συγγραφή της διπλωματικής μου εργασίας.

Θα ήθελα επίσης να εκφράσω ιδιαίτερες ευχαριστίες μου στην Καθηγήτρια κ. Μαργαρίτα Μάκου, στον Επίκουρο Καθηγητή κ. Ηλία Μπιτσάνη, στον Επίκουρο Καθηγητή κ. Απόστολο Τσολάκη και στο Λέκτορα κ. Ιωσήφ Σηφακάκη καθώς και στους συνεργάτες του εργαστηρίου της Ορθοδοντικής για την ουσιαστική συμβολή τους στην εκπαίδευσή μου σε θεωρητικό αλλά και σε κλινικό επίπεδο.

Θέλω να ευχαριστήσω θερμά τους συμφοιτητές και φίλους μου, Κώστα, Αλίνα και Λύδια για τη συνεργασία και τη συμπαράσταση κατά τη διάρκεια των τριών απαιτητικών χρόνων. Οι δυσκολίες ήταν πολλές, αλλά το πνεύμα συνεργασίας, μας βοήθησε να τις ξεπεράσουμε όλες.

Κλείνοντας θα ήθελα να ευχαριστήσω την οικογένειά μου και τους φίλους μου για την υποστήριξή τους στη μέχρι τώρα πορεία μου.

«Η ολοκλήρωση της επιστημονικής εργασίας συγχρηματοδοτήθηκε μέσω του Έργου «Υποτροφίες ΙΚΥ» από πόρους του ΕΠ «Εκπαίδευση και Δια Βίου Μάθηση», του Ευρωπαϊκού Κοινωνικού Ταμείου (ΕΚΤ) του ΕΣΠΑ, 2007-2013».

Contents

Περίληψη

Λέξεις κλειδιά:

Αύξηση, Κρανιοπροσωπικό σύμπλεγμα, Μορφομετρία, Ανάλυση Προκρούστη

Σκοπός:

Οι ασθενείς εμφανίζουν μεγάλη ποικιλότητα στον τρόπο με τον οποίο αυξάνονται. Ωστόσο, ιδιαίτερη βιολογική σημασία εμφανίζει το ερώτημα, εάν ασθενείς με διαφορετικές σκελετικές δυσμορφίες παρουσιάζουν και διαφορετικό τρόπο αύξησης. Το παραπάνω ερώτημα παρουσιάζει μεγάλη σημασία και κατά το σχεδιασμό κλινικών ερευνών. Σκοπός της παρούσας διπλωματικής μεταπτυχιακής εργασίας είναι να διερευνήσει, εάν η κατεύθυνση της αύξησης συσχετίζεται με το αρχικό σχήμα του κρανιοπροσωπικού συμπλέγματος.

Υλικά και μέθοδος:

Το δείγμα αποτελούν 350 πλάγιες κεφαλομετρικές ακτινογραφίες, από 175 φυσιολογικά παιδιά (91 κορίτσια, 84 αγόρια) χωρίς ιστορικό προηγούμενης ορθοδοντικής θεραπείας. Οι ηλικίες που εξετάστηκαν ήταν τα 12 (T1) και 14 (T2) έτη. Η αναζήτηση των ακτινογραφιών έγινε στη βάση δεδομένων American Association of Orthodontists Foundation (AAOF) Craniofacial Growth Legacy Collection και περιελάμβανε ακτινογραφίες από τις μελέτες αύξησης των Bolton, Fels, Iowa και Oregon. Στην κάθε πλάγια κεφαλομετρική ακτινογραφία έγινε ψηφιακή ιχνογράφηση 15 καμπυλών, οι οποίες περιέγραφαν λεπτομερώς το κρανιοπροσωπικό σύμπλεγμα. Στη συνέχεια τοποθετήθηκαν 127 σημεία πάνω στις καμπύλες˙ τα 11 σημεία θεωρήθηκαν σταθερά ενώ τα υπόλοιπα 116 είχαν τη δυνατότητα να ολισθαίνουν πάνω στις καμπύλες τους. Τέλος, εφαρμόστηκε

αλληλεπίθεση Προκρούστη, ανάλυση κυρίων συνιστωσών (PCA) καθώς και two-block partial least squares analysis (2B-PLS) μετά την ολίσθηση των ολισθαινόντων σημείων, έτσι ώστε να ελαχιστοποιηθεί η ενέργεια κάμψης.

Αποτελέσματα:

Οι 10 πρώτες κύριες συνιστώσες (PCs) περιέγραφαν περίπου το 71% της συνολικής διακύμανσης του σχήματος. Το PC1 συχετιζόταν με την ποικιλότητα του σχήματος στην κατακόρυφη διεύθυνση (υπο- και υπεραποκλίνοντα σκελετικά επίπεδα) ενώ το PC2 περιέγραφε κυρίως την ποικιλότητα του σχήματος στην προσθιοπίσθια διάσταση (IIη / IIIη σκελετική σχέση). Το PC3 συσχετιζόταν κυρίως με την ποικιλότητα του σχήματος της γωνίας της κάτω γνάθου. Όλοι οι ασθενείς παρουσίαζαν παρόμοιο διάνυσμα αύξησης στο σχηματοχώρο. Δεν υπήρχε συσχέτιση μεταξύ του αρχικού σχήματος και της έντασης της αλλαγής του σχήματος κατά την αύξηση από το T1 στο T2, αλλά τα αγόρια παρουσίασαν μεγαλύτερη αλλαγή σχήματος από τα κορίτσια. Η κατεύθυνση της αλλαγής σχήματος συσχετίστηκε ασθενώς με το αρχικό σχήμα του κρανιοπροσωπικού συμπλέγματος (RV coefficient: 0.14, $P < 0.001$).

Συμπεράσματα:

Το αρχικό σχήμα του κρανιοπροσωπικού συμπλέγματος έχει ασθενή συνδιακύμανση με την κατεύθυνση της αλλαγής του σχήματος κατά την αύξηση.

Summary

Key words:

Growth, Craniofacial Complex, Morphometrics, Procrustes Analysis

Aim:

There is great variation of growth among individuals. The question whether patients with different skeletal discrepancies grow differently is biologically interesting but also important in designing clinical trials. The aim of the present study was to evaluate if growth direction depends on the initial craniofacial pattern.

Subjects and Method:

The sample consisted of 350 lateral cephalograms of 175 subjects (91 females, 84 males) followed during normal growth without any orthodontic treatment. The examined ages were 12 (T1) and 14 (T2) years. The cephalograms were obtained from the American Association of Orthodontists Foundation (AAOF) Craniofacial Growth Legacy Collection (Burlington, Fels, Iowa and Oregon growth studies). We digitally traced 15 curves on each cephalogram, comprehensively covering the craniofacial skeleton, and located 127 points on the curves, 116 of which were sliding semilandmarks and 11 fixed. Procrustes alignment, principal component analysis (PCA) and two-block partial least squares (2B-PLS) analysis were performed, after sliding the semilandmarks to minimize bending energy.

Results:

The first 10 principal components (PCs) described approximately 71% of the total shape variance. PC1 was related to shape variance in the vertical direction (low/high angle skeletal pattern) and PC2 was mainly related to shape variance in the anteroposterior direction (class II/class III pattern). PC3 was mainly related to the shape variance of the mandibular angle. All subjects shared a similar growth trajectory in shape space. We did not find any correlation between the initial shape and the magnitude of shape change between T1 and T2, but males showed a greater shape change than females. The direction of shape change was moderately correlated to the initial shape (RV coefficient: 0.14, $P < 0.001$).

Conclusions:

The initial shape of the craniofacial complex covaried weakly with the direction of shape change during growth.

Introduction

There is great variation of growth among individuals regarding the growth pattern, the direction of growth and the magnitude or rate of growth[1,2,3,4,5,6]. However, the question whether patients with different craniofacial patterns exhibit different growth remains unanswered. One reason for this is that some researchers study the growth of each anatomic region separately[5,7,8], e.g. mandible, maxilla, or by applying a partial analysis of the craniofacial complex instead of a comprehensive one regarding all planes of space[9,10,11]. Moreover, comparisons between the results of different articles are difficult, because they use different analysis methods such as finite element method[12], tensor analysis[13], conventional cephalometric measurements[14]. Other methods used to study craniofacial growth are polynomial regression techniques[15], Procrustes analysis[16] and others[5,17,18].

Furthermore the data in the literature are confusing. One reason for this is that growth direction, growth rate or growth velocity and growth amount are not examined in a clear way. Several researchers study the amount and direction of growth with reference to different reference planes (relative growth behavior) such as S-N[7,14,19,20,21,22] whilst others record the movement of a single point along a particular axis[9,19,21,22] . Additionally, the results might be influenced by the superimposition method used in each study[23]. Some differences are related to the initial sample studied, e.g. the growth of skeletal Class II and skeletal Class III patients did show several differences[5,15,24,25]. The question remains, whether patients with a different craniofacial shape, present different growth referring to the direction, amount and velocity. The answer to this question is also relevant when designing a randomized controlled trial, since it is generally supposed that patients with similar shape characteristics respond in a more similar way to certain treatment modalities, but this assumption lacks of evidence.

There is also a problem regarding the terminology. Each researcher attributes its own definition to the term ''growth''. Growth of the craniofacial complex includes both change in size and change of shape. The evaluation of growth by studying a number of distances and angles on lateral cephalograms is still widely used in everyday clinical practice, despite the fact that the traditional cephalometric approach has been proved inappropriate to describe shape changes in the craniofacial complex[26,27]. In this research we focused on shape, so we used geometric morphometrics (GM) in order to keep size apart and avoid its confounding effect.

The aim of our study was to evaluate with geometric morphometrics how shape changes during two particular ages and whether this change is related to the initial craniofacial pattern.

Materials and Methods

We searched the American Association of Orthodontists Foundation (AAOF) Craniofacial Growth Legacy Collection for subjects fulfilling our inclusion criteria. We included in our sample subjects of both sexes, without any orthodontic treatment in the past and 2 lateral cephalograms at age 12 (T1) and 14 (T2). The ages ranged from 12 ± 3 months to 14 ± 3 months. Our initial search resulted in 227 subjects, with 454 radiographs in total from Burlington, Fels, Iowa and Oregon growth studies. After receiving high resolution images we examined all radiographs and applied following exclusion criteria: 1) radiograph with fixed appliances 2) poor quality of image 3) radiograph taken with open mouth 4) extreme craniofacial pattern or syndrome. We excluded 70 radiographs due to subjects wearing fixed orthodontic appliances. Our intention was to study shape change due to growth, so we left the confounding parameter of orthodontic treatment apart. Thirty four radiographs were also excluded from our final sample due to poor quality (open mouth, poor condition of images). The final sample consisted of 175 subjects (91 females, 84 males), 65 of which were from Burlington, 53 from Iowa, 29 from Fels and the remaining 28 from Oregon Growth Study. *(Table 1, Table 2)*

Table 1: Sample size by region.

	Burlington	**Fels**	**Iowa**	**Oregon**	**Total**
Initial sample	78	45	68	36	**227**
Poor quality	4	8	5	0	**17**
Fixed appliances	9	8	10	8	**35**
Final sample	65	29	53	28	**175**

Table 2: Descriptive statistics.

Growth Study	Males	Initial Age	Final Age	Females	Initial Age	Final Age	Total	Initial Age	Final Age
		Average (SD)	Average (SD)		Average (SD)	Average (SD)		Average (SD)	Average (SD)
Burlington	**30**	12.03 (0.06)	14.04 (0.08)	**35**	12.03 (0.05)	14.05 (0.07)	**65**	12.03 (0.05)	14.04 (0.07)
Fels	**14**	12.00 (0.02)	13.99 (0.04)	**15**	12.02 (0.03)	14.00 (0.06)	**29**	12.01 (0.03)	14.00 (0.05)
Iowa	**28**	11.99 (0.03)	13.99 (0.03)	**25**	11.99 (0.03)	14.00 (0.05)	**53**	11.99 (0.031)	13.99 (0.04)
Oregon	**12**	12.04 (0.07)	14.01 (0.09)	**16**	11.99 (0.10)	14.02 (0.07)	**28**	12.02 (0.09)	14.02 (0.08)
Total	**84**	**12.01 (0.05)**	**14.01 (0.06)**	**91**	**12.01 (0.06)**	**14.03 (0.07)**	**175**	**12.01 (0.06)**	**14.02 (0.06)**

Fifteen continuous curves were digitized by using Viewbox 4.1 software (dHAL software, Kifissia, Greece) on each lateral cephalogram in order to comprehensively capture the shape of the craniofacial complex. Some structures were captured with a double outline and in order to minimize landmark identification error, we selected the mean (midpoint) of the two shape outlines. Curves cannot be used directly in GM, so we placed 127 landmarks on the curves, in order to describe them in detail. We selected two different types of landmarks: 11 points could be easily identified by local anatomy and therefore were considered homologous among subjects and were characterized as fixed points. Fixed points are customary cephalometric points such as anterior nasal spine (ANS) or basion (Ba). The remaining 116 points were semilandmarks and allowed us to describe the shape of a curve, even when there were no anatomical features along the curve[28,29,30,31,32]. These points were initially placed at equidistant positions on their corresponding curve, but then they were allowed to slide to a new position that minimized bending energy. The final position, obtained after iteratively sliding three times, was considered homologous between subjects[29,31]. *(Figure 1and Table 3)*

Figure 1: Curves traced on lateral cephalogram. Red cross: fixed point; green cross: sliding semilandmark.

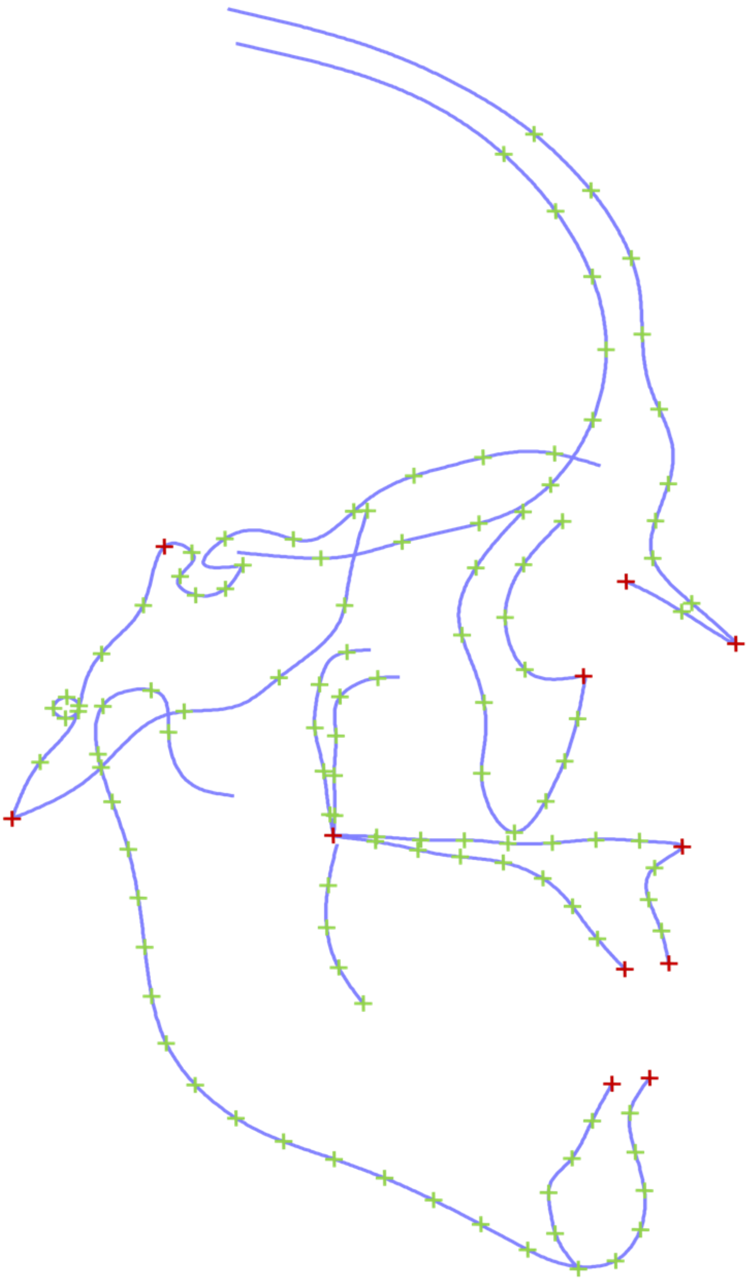


Table 3: Description of curves and number of points placed on each curve.

Curve	Description	Number of Points
Porion	External auditory meatus	4
External frontal - Nasal	External cortical plate of frontal bone and nasal bone	14
Sella - Basion	From tuberculum sellae to posterior clinoid process, dorsum sellae, along clivus, to Basion.	12
Endocranial frontal	From frontal sinus, along roof of orbit and planum sphenoidale, to anterior clinoid processes	9
Internal frontal - Sella	Internal cortical plate of frontal bone, along the cribiform plate of the ethmoid, the superior surface of the sphenoid body, to tuberculum sellae	10
Sphenoethmoidale	From fronto-sphenoethmoidal suture to Basion, along the anterior border of the body and the greater wings of the sphenoid bone and the exocranial surface of basioccipital	8
Orbit	Anterior border of the zygomatic bone, terminating at Orbitale	5
Zygomaticomaxillary	From the posterior margin of frontal process of the zygomatic bone to the zygomatic process of the maxilla	10
Maxilla 1	From PNS anteriorly along the nasal floor, around ANS, and inferiorly along the alveolar process to supradentale	11
Maxilla 2	From PNS, along the outline of the palate, to the cervix of the maxillary incisors	7
PTM1	External surface of maxillary tuberosity	7
PTM2	Anterior surface of pterygoid process of sphenoid bone	7
Mandible	From infradentale, along the external outline of the mandible and around the condyle, to the anterior neck of the condyle	19
Symphysis	The lingual cortical plate of the symphysis	7
Anterior ramus	Anterior border of ramus from the level of the palate to the distal of the 1st mandiblular molar	4

The tracings were superimposed by generalized Procrustes alignment and orthogonal projection onto the tangent plane was applied for extraction of Procrustes coordinates. These were subsequently fed to principal component analysis (PCA) to obtain principal components (PCs) of shape variation. The PCs describe the shape pattern of our sample and are used to place each subject in a so-called 'shape-space'. We used following three criteria: rnd-lambda, the broken stick criterion and the avg-rnd to evaluate the number of PCs which are statistically significant[33]. Eighteen first PCs were specified as significant by these criteria.

We performed two-block partial least squares (2B-PLS) analysis[34] for the whole sample and for each gender separately, so as to investigate any covariation between the initial position of each subject in the shape-space and the direction of its shape change during growth. The analysis was performed with MorphoJ software[35] and the RV coefficient evaluated the covariation strength[36].

Method Error

In order to estimate the error of the method, 30 radiographs were randomly selected and redigitized by the same investigator after a minimum of 4 weeks. Random error was expressed as the distance between the repeated measurements in shape-space in comparison with the total variance.

Results

Method Error

Mean random error of the 30 repeated tracings was 4.43 percent, expressed as a percentage of the total shape variance (range: 2.70 - 7.16 percent, SD= 1.15 percent). This error is considered small enough to validate the results of our research as reliable.

Generalized Procrustes Superimposition and PCA

Due to Procrustes alignment four degrees of freedom are lost, therefore 250 non-zero PCs were computed, instead of 254 PCs produced by our 127 landmarks. Eighteen first PCs (PC1-PC18) were considered statistically meaningful and described 84% of the total shape variability *(Table 4)*. The 3 first PCs embodied approximately 40% of total shape variability, PC1 described 19%, PC2 13% and PC3 around 8% of total shape variability. PC1 described mainly the vertical dimension of the shape of the craniofacial complex, namely hyper divergent or hypo divergent skeletal planes *(Figure 2a)*. PC2 mostly described the variability of the anteroposterior dimension, with Class II skeletal patterns on one extreme and Class III patterns on the other *(Figure 2b)*. PC3 was mainly related to the shape variance of the mandibular angle: low values represent low gonial angles and increased posterior facial height whereas the opposite happens for high values *(Figure 2c)*.

Table 4: Principal components. Percent variance of total shape variability.

Principal Component	% variance	% cumulative variance	% variance	% cumulative variance	% variance	% cumulative variance
	Both Ages		12 years		14 years	
PC1	19.3%	19.3%	19.4%	19.4%	19.4%	19.4%
PC2	12.9%	32.3%	12.8%	32.2%	12.7%	32.2%
PC3	7.8%	40%	7.6%	39.8%	7.7%	39.9%
PC4	7.1%	47.2%	6.5%	46.3%	6.9%	46.7%
PC5	5.9%	53.1%	6.2%	52.5%	6%	52.7%
PC6	4.8%	57.9%	5%	57.5%	4.9%	57.6%
PC7	3.9%	61.9%	4%	61.4%	4.1%	61.7%
PC8	3.6%	65.5%	3.8%	65.2%	3.7%	65.4%
PC9	2.7%	68.1%	2.9%	68.1%	2.9%	68.3%
PC10	2.7%	70.8%	2.6%	70.7%	2.6%	70.9%

Figure 2a: PC1 shape variability at ±3SD.

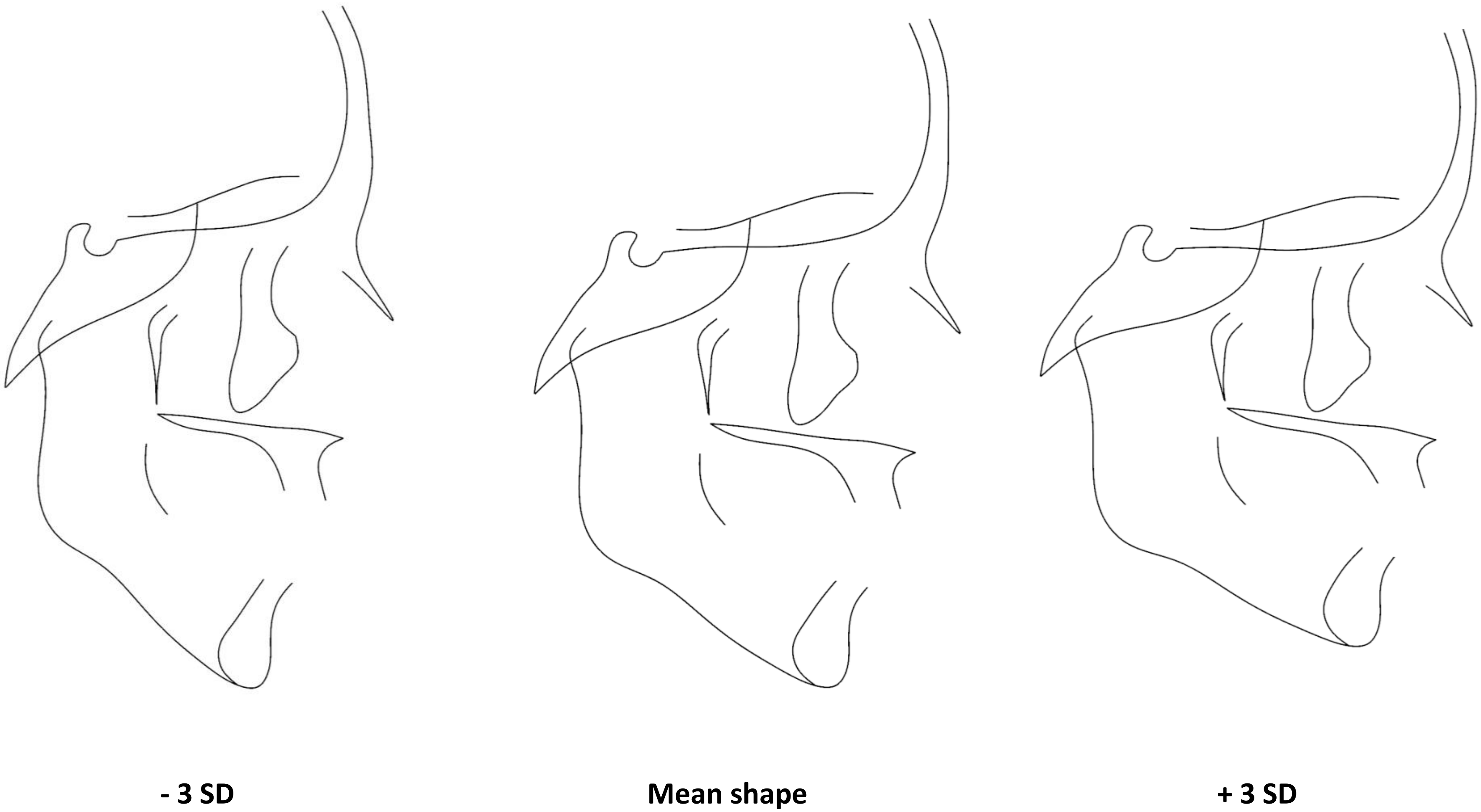
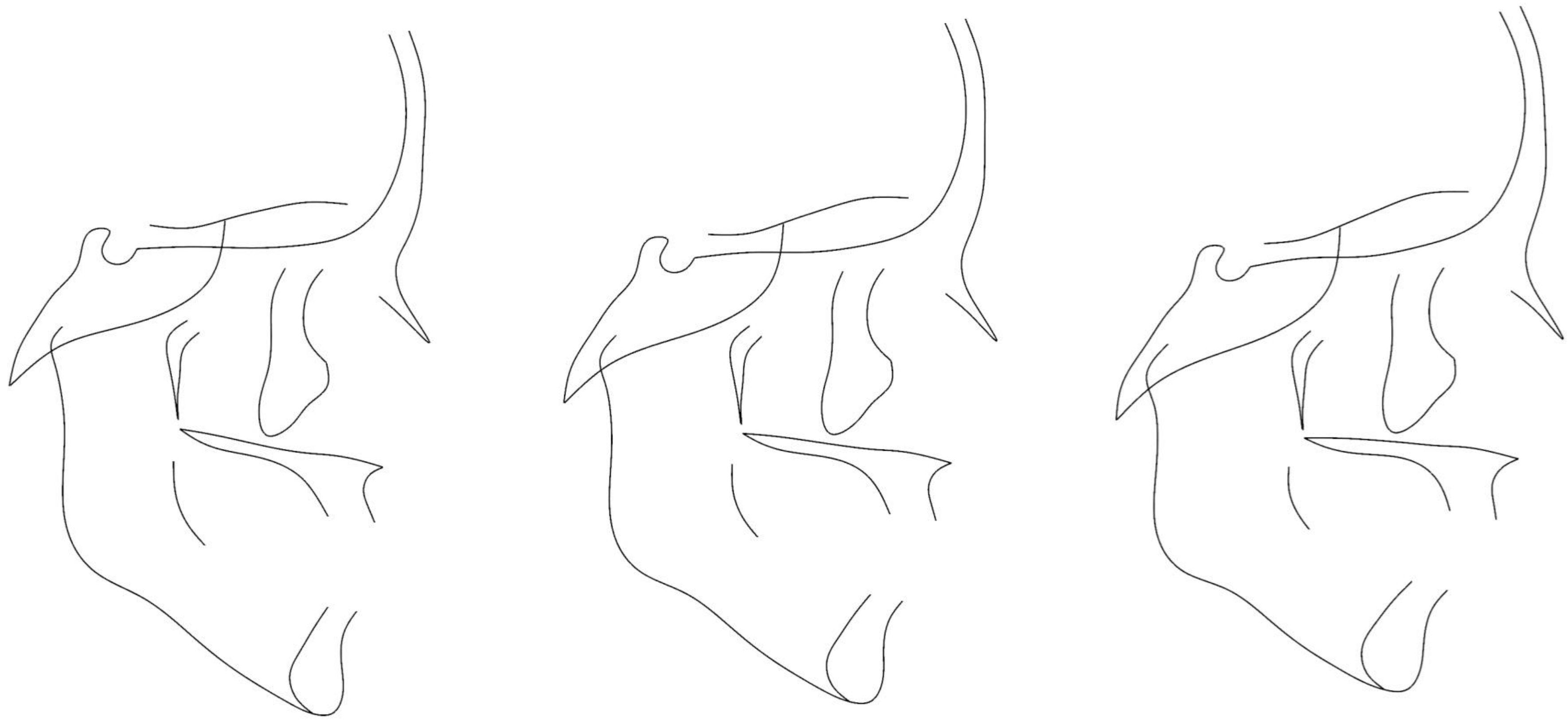


Figure 2b: PC2 shape variability at ±3SD.



- 3 SD **Mean shape** **+ 3 SD**

Figure 2c: PC3 shape variability at ±3SD.

- 3 SD **Mean shape** **+ 3 SD**

Geographic region and initial shape difference

After applying permutation tests, we noted a statistically significant difference among the populations of all regions at initial age (P<0.01). Greater shape difference was noted between Fels and Oregon at 12 years with 6.60% shape difference of the total shape variability at initial age. A statistically significant difference was also observed at final age among all regions (P<0.01). We decided to pool the subjects from all regions in order to increase generalisability of the results and because the inter-region shape differences were small relative to the total shape variability.

Age, sex and shape correlation

A statistically significant difference was noted between the two sexes both at 12 years and at 14 (10000 permutations: P=0.03 and P= 0.01 respectively). Shape dimorphism was 3.60% of the total shape variability at T1 and increased to 4.14% at T2. There was a significant shape change with growth from 12 to 14 years for the whole sample and for each gender separately (10000 permutations, P<<0.01). *(Table 5, Figure 3, 4, 5)*

Table 5: Permutation tests describing shape difference.

Males 12 - Males 14	Females 12 - Females 14	Males and females 12 - Males and females 14
10000 Permutations, P<0.01	10000 Permutations, P<0.01	10000 Permutations, P<0.01

Figure 3: Shape changes from 12 to 14 years. Blue: 12 years. Green: 14 years. Left: Procrustes superimposition on all points. Right: Procrustes superimposition on cranial base points.

Figure 4: Shape change for males from 12 to 14 years. Procrustes superimposition on all points. Dotted line: 12 years. Blue line: 14 years

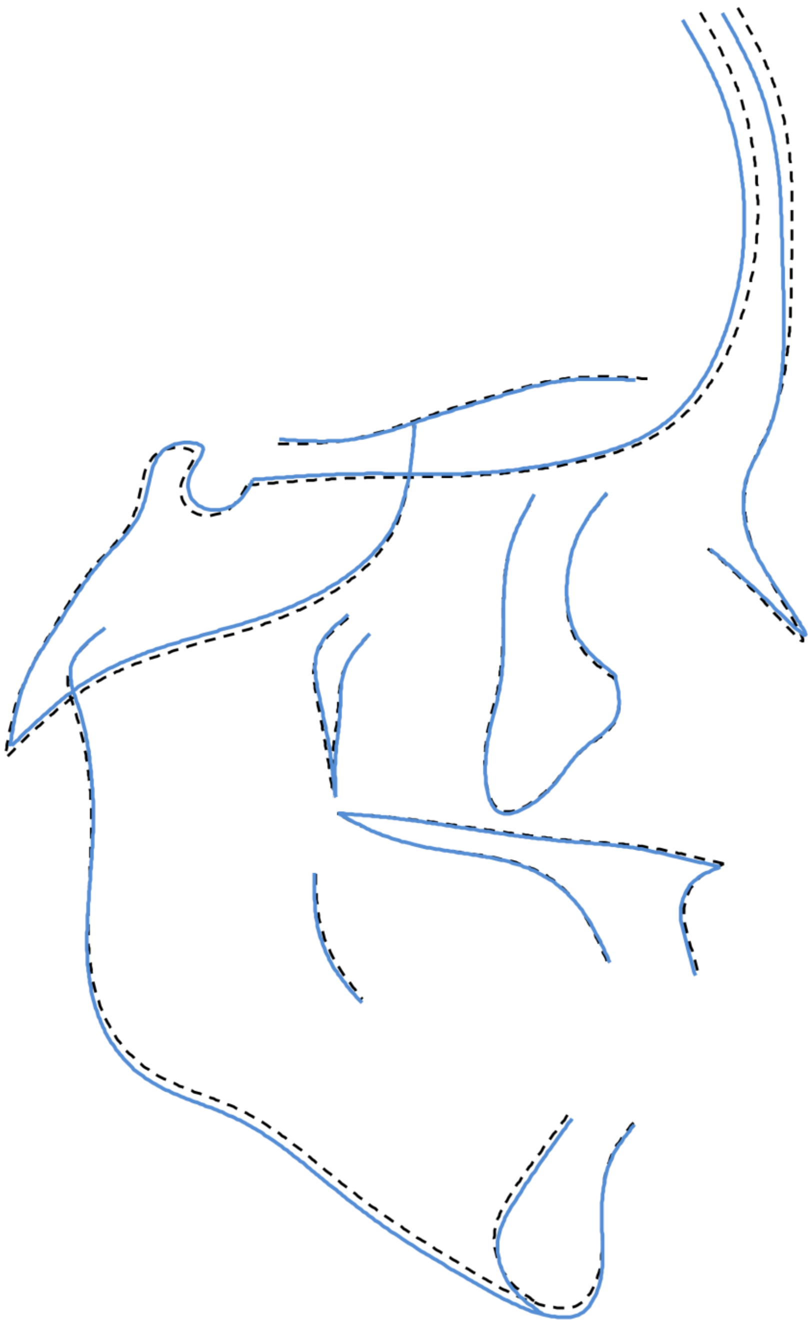
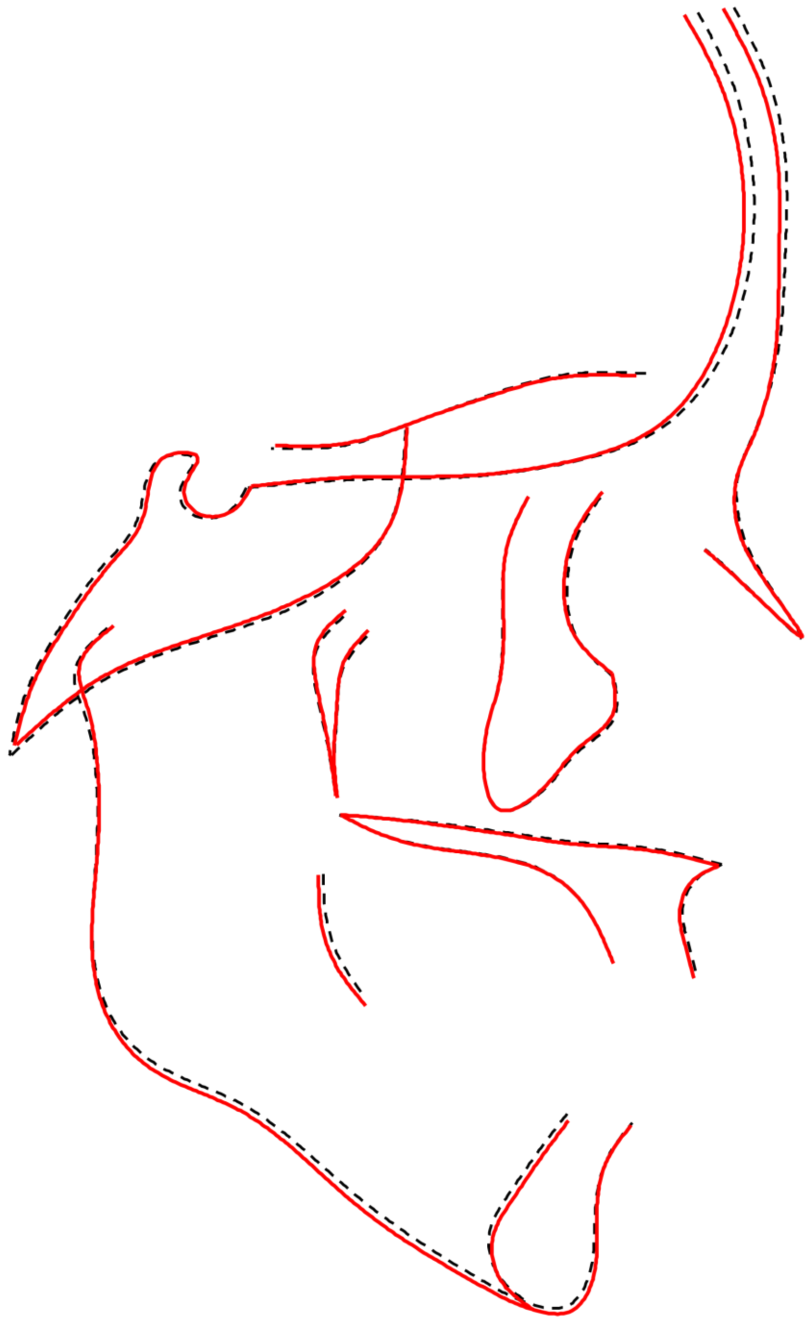


Figure 5: Shape change for females from 12 to 14 years. Procrustes superimposition on all points. Dotted line: 12 years. Red line: 14 years



Magnitude and direction of shape change

The shape change for both males and females was in the same direction, but the male vector was longer, indicating a more pronounced shape change *(Figure 6, 7)*. We used a t-test assuming unequal variances between the two groups (P<<0.01). Males experienced a shape change of 6.10% of the total shape variability, whereas females changed their craniofacial shape 4.84%. *(Table 6)* Regression analysis showed no correlation between initial shape and magnitude of shape change (males: P= 0.17, R^2=16%, females: P=0.09, R^2=17%).

Figure 6: Direction of shape change from 12 to 14 years for the whole sample in the shape-space. Blue spheres: 12 years. Green spheres:14 years

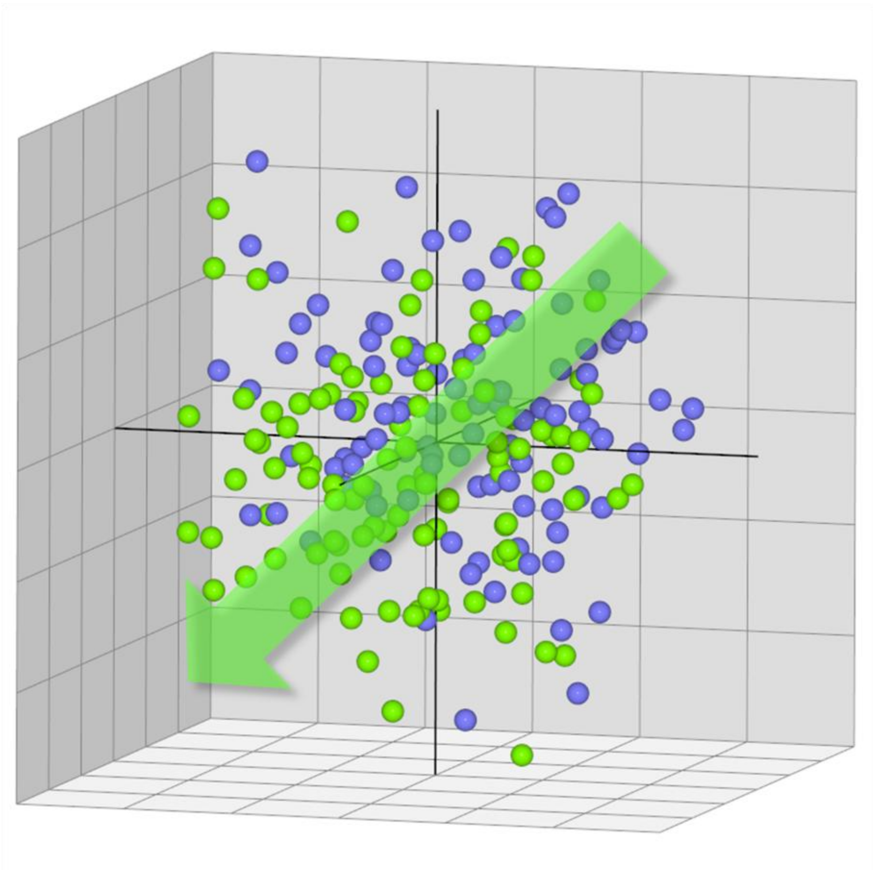


Figure 7: Vectors of shape change for males and females. Pink: Females initial position, Red: Females final position, Light Blue: Males initial position, Blue: Males final position.

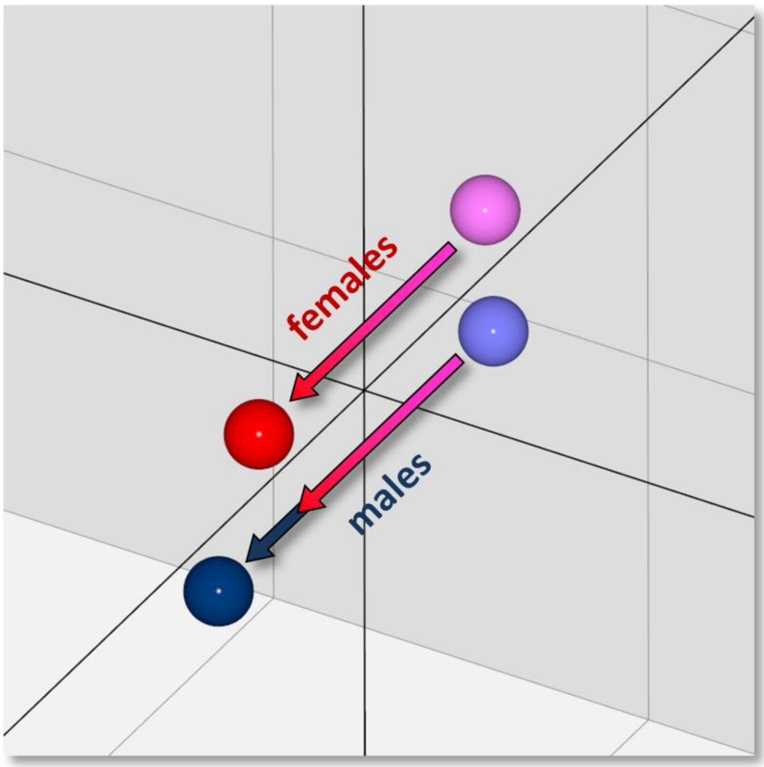


Table 6: t-test for magnitude of shape change among males and females.

	Males Growth	Females Growth
Mean	0,033	0,028
SD	0,007	0,006
Observations	84	91
t Stat	4,302	
P(T<=t) two-tail	2,92E-05	

Two-block partial least squares analysis (2B-PLS)

Shape change covaried significantly but weakly with initial shape (RV coefficient: 0.14, $P < 0.001$). We investigated each gender separately with similar results (males: RV = 0.24, $P<0.01$, females: RV = 0.2, $P=0.03$), other than an expected inflation of the RV value due to smaller sample size[37]. PLS1 accounted for more than 25% of the total covariance and PLS2 for approximately 17%. *(Table 7)*

Table 7: PLS percent variance.

	Males + Females **% Total covariance**	**Males** **% Total covariance**	**Females** **% Total covariance**
PLS1	25.32	28.35	26.08
PLS2	16.93	13.38	13.84
PLS3	12.40	11.37	10.86
PLS4	6.62	7.05	8.16
PLS5	5.67	5.83	6.52
	RV coefficient: 0.14, **P < 0.00**	**RV coefficient: 0.24,** **P< 0.00**	**RV coefficient:0.20,** **P= 0.03**

PLS1 described differences in the relative position of the mandible and the posterior cranial base along an anteroposterior axis (roughly aligned from Ba to Pg) *(Figure 8, 9)*. Subjects with a relative anterior cranial base position and posterior mandibular position (here: at the positive extreme of the PLS1 axis) are expected to exhibit a shape change towards a more anterior position of the mandible, in relation to the average shape change *(Figure 10)*. Such a growth pattern would result in improvement of the overall craniofacial shape, bringing it closer to the population average. Likewise, subjects at the negative extreme of the PLS1 axis, who show relative mandibular protrusion, would also improve in overall shape. The two extremes ,PLS1+ and PLS1- exhibit different craniofacial shapes, which are likely to show the greatest difference in the direction of their shape change during growth.

Figure 8: Block 1 PLS1 from MorphoJ.

Figure 9: Light blue: PLS1+ extreme subject at T1, dark blue: average subject at T1, red: PLS1- extreme subject at T1.

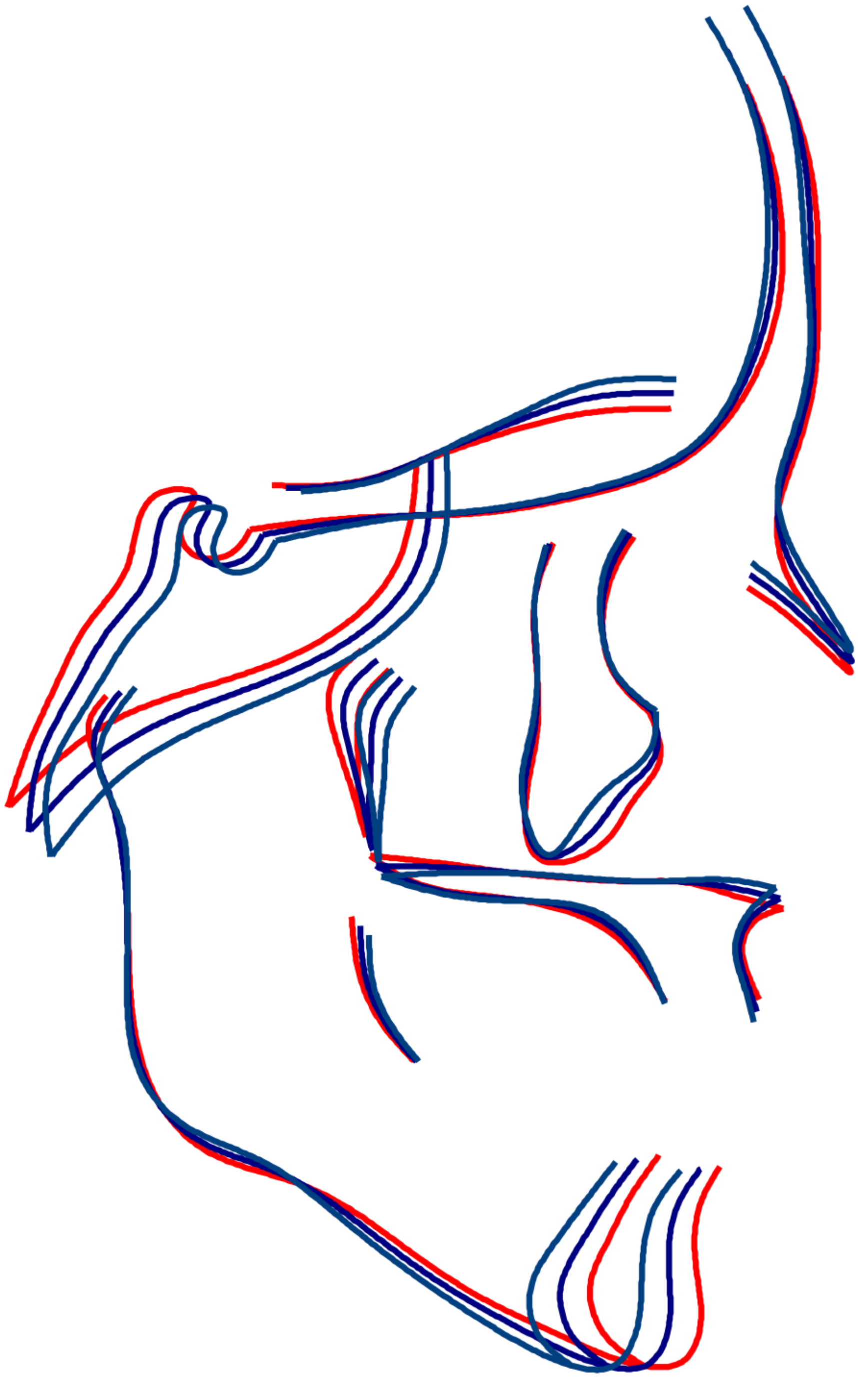
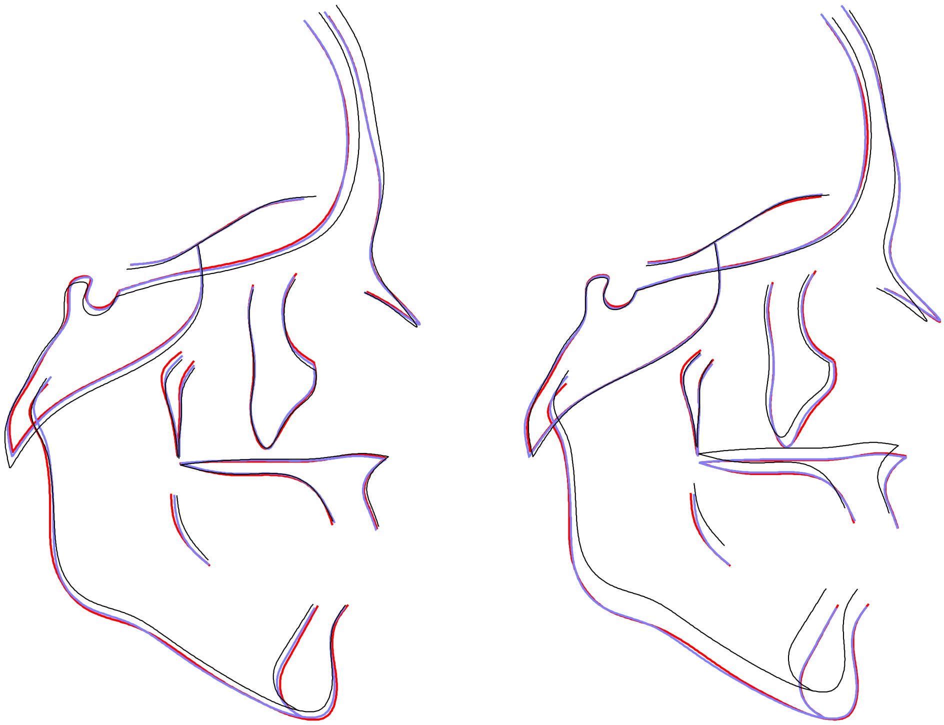


Figure 10: Blue: average growth shape change, red: growth change taking into account the PLS1 covariation. Shape changes exaggerated x2.
Left: Procrustes superimposition on all points, right: Procrustes superimposition on cranial base points.



PLS2 contrasted subjects in the vertical direction, with hyperdivergency at one extreme (here: positive PLS2) and hypodivergency at the other (negative PLS2) *(Figure 11, 12)*. In contrast to PLS1, the 2B-PLS analysis showed that subjects at the extremes of the PLS2 pattern would tend to worsen with growth, mainly due to shape changes at the gonial angle: increasing an already high mandibular plane angle, or decreasing an already low angle *(Figure 13).*

Figure 11: Block 1 PLS2 from MorphoJ.

Figure 12: Light blue: PLS2+ extreme subject at T1, black: average subject at T1, red: PLS2- extreme subject at T1.

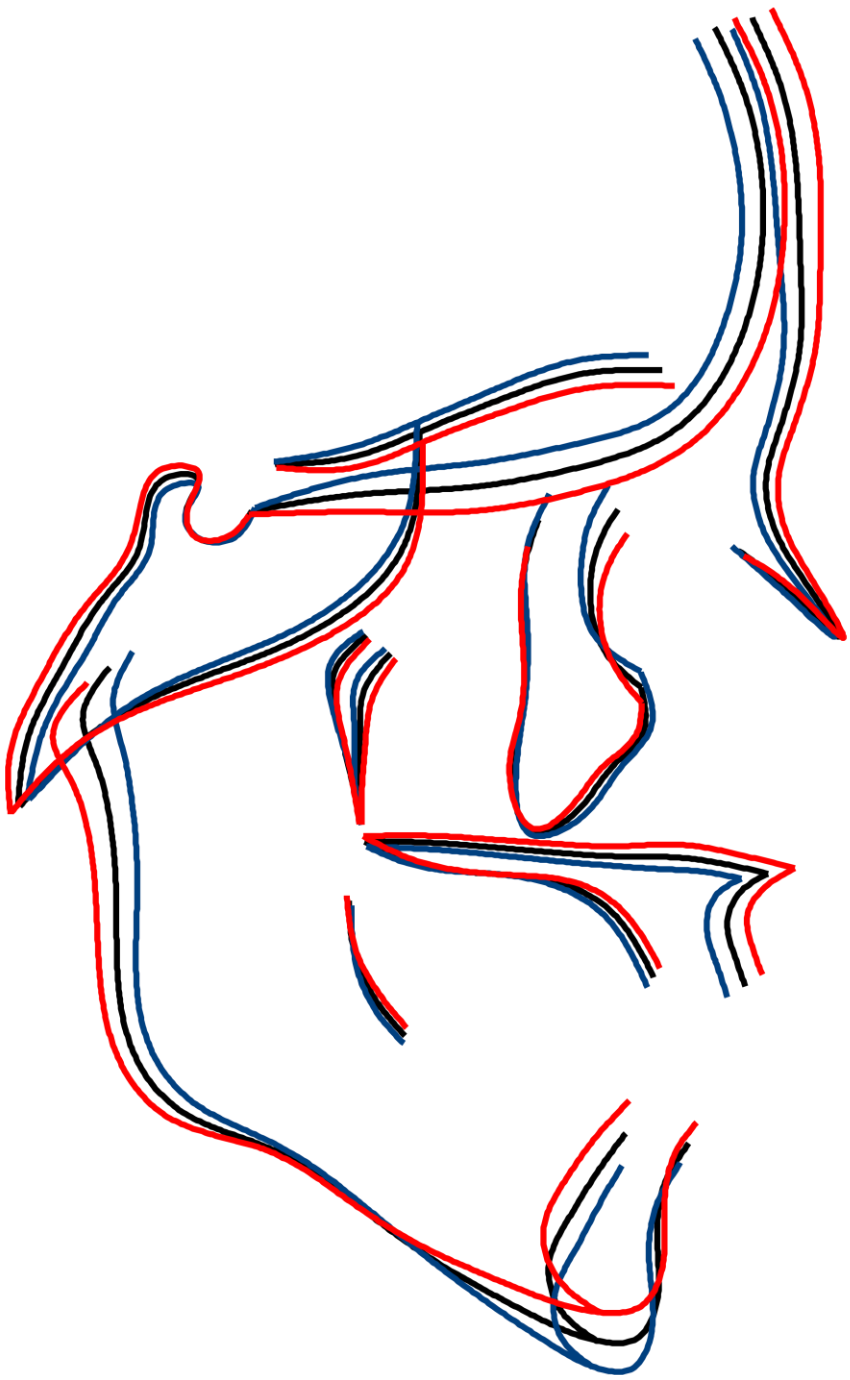
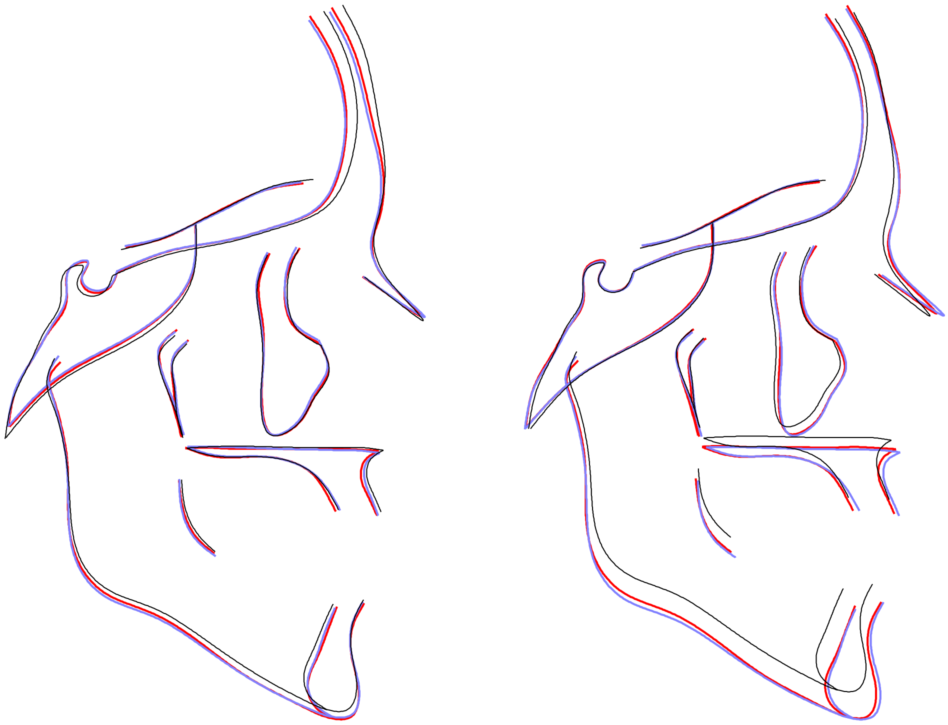


Figure 13: Blue: average growth shape change, red: growth change taking into account the PLS2 covariation. Shape changes exaggerated x2.
Left: Procrustes superimposition on all points, right: Procrustes superimposition on cranial base points.



Discussion

Although there are no clear guidelines to estimate sample size in geometric morphometric studies[37], we followed the results of Fruciano et al.[38], since we mainly examined covariation. We aimed for a sample size larger than the minimum of 100 subjects required to stabilize the RV coefficient[38] and comparable to the sample size of studies investigating craniofacial variation[39,40]. Final sample size was limited by the availability of subjects from the selected growth studies of the AAOF Craniofacial Growth Legacy Collection that fulfilled our inclusion and exclusion criteria. The sample consisted of normal untreated subjects of white-Caucasian race who lived around the 1950's and exhibited a wide variety of craniofacial shapes. The historical nature of the data might not accurately reflect the shape change trends of a contemporary population. In addition, the subjects were pooled from different geographical regions with potentially different environmental conditions, nutritional habits or genetic ancestry, all of which might reflect on craniofacial shape and growth [41,42].

The use of lateral cephalograms is a recognized limitation, but unavoidable with this material. In an effort to capture craniofacial shape more comprehensively than the customary collection of cephalometric landmarks affords, we used a total of 127 points, distributed on traditional anatomic structures and additionally on structures not usually considered in cephalometric studies, such as the pterygomaxillary fissure, the zygomatic process of the maxilla and the anterior border of the ramus. A small number of these points were type I landmarks[13,32], i.e. identified by local anatomy (e.g. ANS, PNS); we excluded all type III landmarks (e.g. A point, B point, Pg, Me, Gn) in order to avoid bias, and used sliding semilandmarks to achieve closer homology[28,29,30].

Due to the methodological differences described above, especially the use of non-conventional landmarks and the emphasis on geometric shape measures and concomitant exclusion of linear and angular measurements, our findings are difficult to compare with other studies.

Generalized Procrustes Superimposition and PCA:

The largest PC was related to variability of the craniofacial complex in the vertical direction. This is in contrast to the orthodontic community's traditional opinion that discrepancies in the sagittal plane are more extensive and thus more important for orthodontic diagnosis. However, several reports support our findings[26,39,43]. Despite the fact that skeletal discrepancies in the anteroposterior direction are easily recognized, vertical discrepancies seem to be more prominent.

Shape changes

The craniofacial shape of males changed more than that of females during the examination period *(Figure 4, 5, 7)*. This is consistent with the results of other researchers[3,9,20] that boys experience more growth, and therefore presumably more shape change, during adolescence than girls. Some researchers noted also that, prior to the onset of puberty, girls have achieved a greater proportion of their growth than boys[3,6]. We found that the shape of the mandible changed more than that of the maxilla, leading to a slight improvement in the sagittal relation of the craniofacial complex, but the overall facial pattern was maintained during growth, so, e.g., a hypodivergent subject is unlikely to become hyperdivergent *(Figure3)*. These results are in agreement with those of other researchers who found that the mandible grows more than the maxilla during adolescence[3,44]. Although most subjects did not divert substantially from the mean direction of shape change, we observed individual variability, irrespective of gender or initial shape of the craniofacial complex. This is consistent with other studies that individual growth patterns do not necessarily follow the group pattern[3], and that regardless of facial type, similar growth direction has been demonstrated[6] *(Figure 6)*.

The lower border of the mandible and the region of the symphysis exhibited apparent shape changes, despite the fact that the symphysis is considered to be a relatively stable region of the craniofacial complex[45] *(Figure 3)*. The changes at the symphysis are attributed to the Procrustes superimposition, which distributes shape differences over the whole landmark configuration. Slight shape changes were noted at the ramus of the mandible. The mandible moved clockwise and forwards in relation to the other craniofacial structures. Chang et al.[8] reported that the condylar head of the mandible showed the greatest shape change, presenting an upward and forward growth. They also observed comparable shape changes to ours between the genders, for a similar growth interval. We noted a counter-clockwise rotation of the occlusal plane and a decrease of facial convexity, in line with other studies[15]. Our subjects experienced an anterior rotation of the mandible *(Figure 3)*. As a result, mandibular plane angle showed a tendency to decrease over ages, which is in agreement with the results of Buschang et al.[7], who reported a 2^{o} decrease between the ages 12 and 14. Regarding the G-axis[22], defined by sella (S) superiorly and G-point inferiorly (geometric center of the symphysis), we did not notice any clinical difference among genders. On the other hand, the G-axis decreases in female subjects from 6 to 19 years, whereas increases in male subjects for the same age period[22]. Our finding that the directions of shape change were almost parallel between subjects confirms that there are no significant differences in growth direction (angle N-S-Gn), either for subjects showing a vertical or horizontal shape pattern[5]. We did not notice any difference between the genders regarding the direction of shape change, which is consistent with previous results[46]. Mitani et al. suggested that the morphologic characteristics established before the pubertal growth peak do not change and are maintained thereafter[47]. On the contrary, it has been reported that males showed significantly more forward mandibular rotation than females[20]. We found that there was no correlation between initial shape and magnitude of shape change, that is contrasting to the finding that Class III subjects experienced greater mandibular growth than subjects with normal occlusion, both in males and females[25]. This might be attributed to size changes during growth or to a misleading classification of subjects when using angular and linear measurements from conventional cephalometrics.

We noted only slight shape changes of the maxilla during our observation period. Both, Procrustes superimposition on all points and on cranial base points revealed small downward direction of shape change of the maxilla *(Figure 3)*. Although the description of the maxillary growth as a ''downward and forward migration'' is considered imprecise, because it is a generalized expression of the growth direction[19] and in relation to the other structures, which do also grow, this movement is in agreement with our results. We also noted a slight increase of the angle of the C-axis vector, defined from sella (S) superiorly to M-point inferiorly (geometric center of the maxilla)[19]. Previously it has been reported, that the C-axis vector has a tendency to increase during growth[19]. Simultaneously, we confirmed the results that the palatal plane/C-axis angle increases in both genders[19].

Regarding the cranial base, we noticed a forward direction of shape change for both genders. In the past, it has been stated that cranial base angle tends to remain relatively constant between 5 and 15 years of age[14]. The cranial base grows less during adolescence relative to its final size than the mandible or maxilla does[3]. Others showed that neither sex presented statistically significant differences in cranial base angle, although both showed a slight decrease with growth[46].

In the region of the nasal and of the frontal bone we noticed some shape changes in both genders. The frontal bone changes were not expected but can be explained by the fact that we were looking at a Procrustes alignment and size has been equalized. The frontal bone at T2 is therefore relatively smaller than it would be (because the mandible and maxilla are relatively larger); since the frontal bone is similar to a circle, if it becomes smaller, its curvature increases and this is why it seems to move posteriorly at the superior part. Moreover, pneumatization of the frontal and ethmoid sinuses, results in greater shape changes of the neighboring structures.

Shape covariation:

The RV value of 14.22 per cent shows that there is significant covariation between the initial craniofacial shape and the direction of shape change, but there is also enough leeway for other variables affecting the direction of shape change. The PLS1 covariance pattern indicates that the sagittal discrepancy tended to improve, i.e. Class II subjects tended to become less Class II, and Class III subjects less Class III.

This is consistent with studies showing a decrease of the angle of convexity with age in Class II division 1 patients[15,48,49]. On the other hand, there are several studies which propose that sagittal disharmony does not improve with growth, but the deficiency tends to worsen, mainly attributed to mandibular growth[14,18,24,50,51].

Regarding PLS2 covariance, subjects with a hyperdivergent skeletal pattern tended to become more hyperdivergent during our examination period and hypodivergent subjects likewise diverted from the average towards a more hypodivergent craniofacial shape. Bishara et al[6] found that all three facial types (long, average, short) maintained the existing growth pattern during growth, by a tendency towards worsening their skeletal relationships. Similar results have been proposed for vertical growers[5].

Although the RV coefficient, which described the total covariation of the initial shape with the direction of shape change, was statistically significant, it was not very strong. This suggests that there are other factors that may affect the direction of shape change during growth. Numerous growth prediction methods have been proposed[52,53,54], but with limited success. GM and covariation analysis can provide a confidence interval for the predicted craniofacial shape, based on average changes augmented by covariance patterns; this is the subject of on-going research. Our findings support clinical experience that calls for special attention when planning treatment of patients with vertical discrepancies. It might also be interesting to examine growth changes with the proposed method for a longer time period, instead of the 2 years we studied.

Conclusions

1) Ten first PCs described approximately 71% of the total shape variability.
2) Most subjects shared a similar growth direction.
3) The vectors of shape change were similar for all geographic regions.
4) There was no correlation between the initial shape of the craniofacial complex and the magnitude of shape change.
5) Males showed a greater shape change than females.
6) The initial shape difference among the sexes increased after two years of active growth.
7) Shape change covaried significantly but weakly with initial shape.

Conflict of interest statement

No competing personal and financial interests exist.

Acknowledgements

I would like to thank the American Association of Orthodontists Foundation (AAOF) for the availability of all records used in the present study.

This study was made possible by use of material from the Burlington Growth Centre, Faculty of Dentistry, University of Toronto, which was supported by funds provided by Grant (1) (No. 605-7-299) National Health Grant (Canada), (data collection); (2) Province of Ontario Grant PR 33 (duplicating) and (3) the Varsity Fund (for housing and collection).

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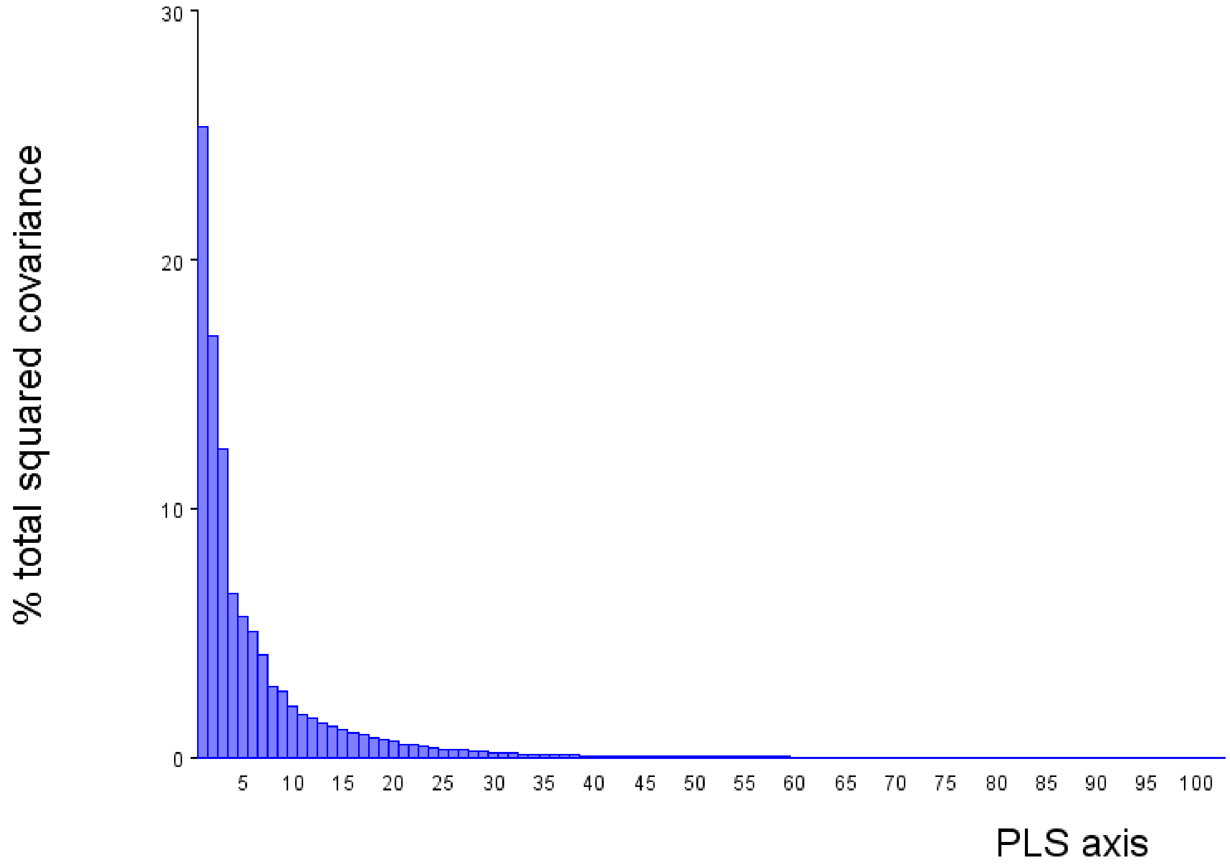
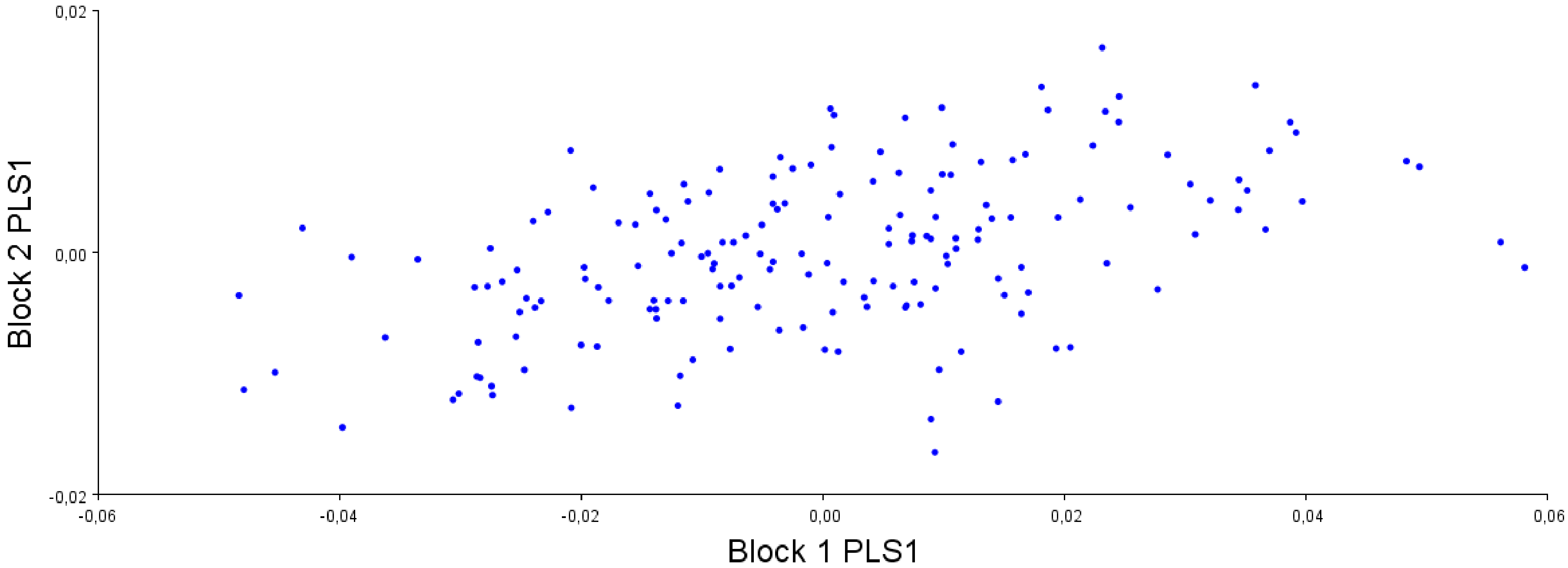
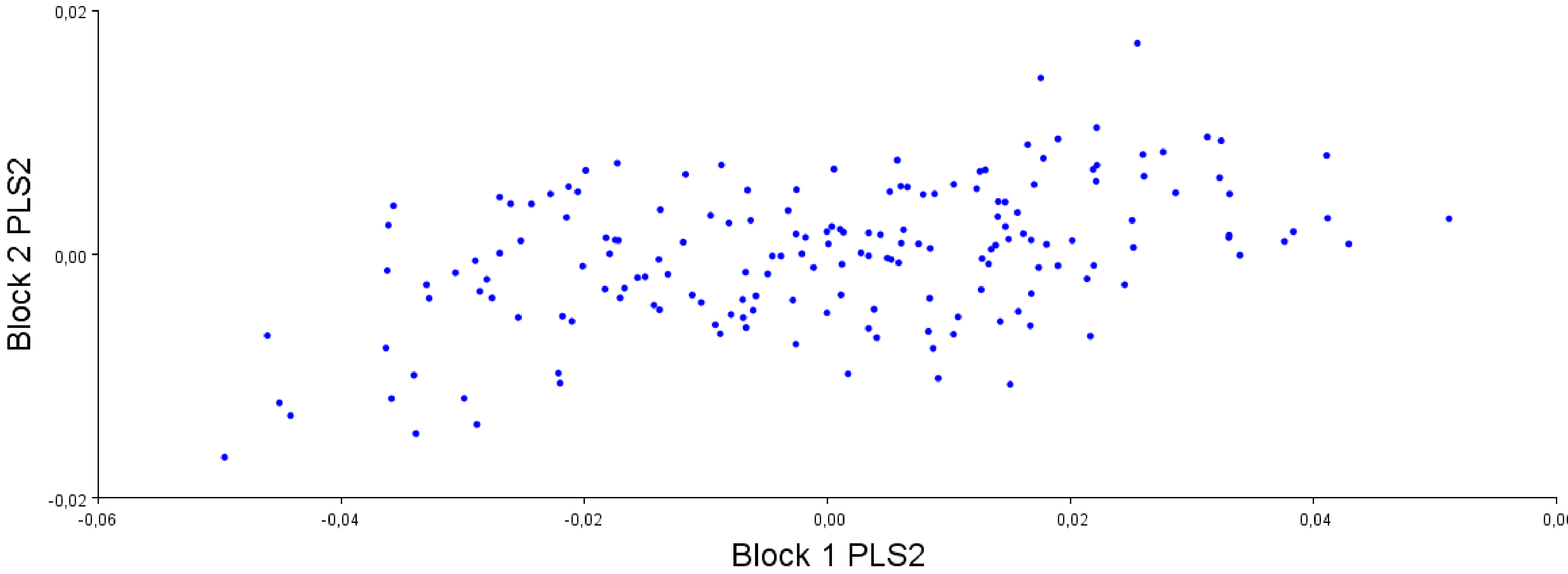
Appendix - Raw Data

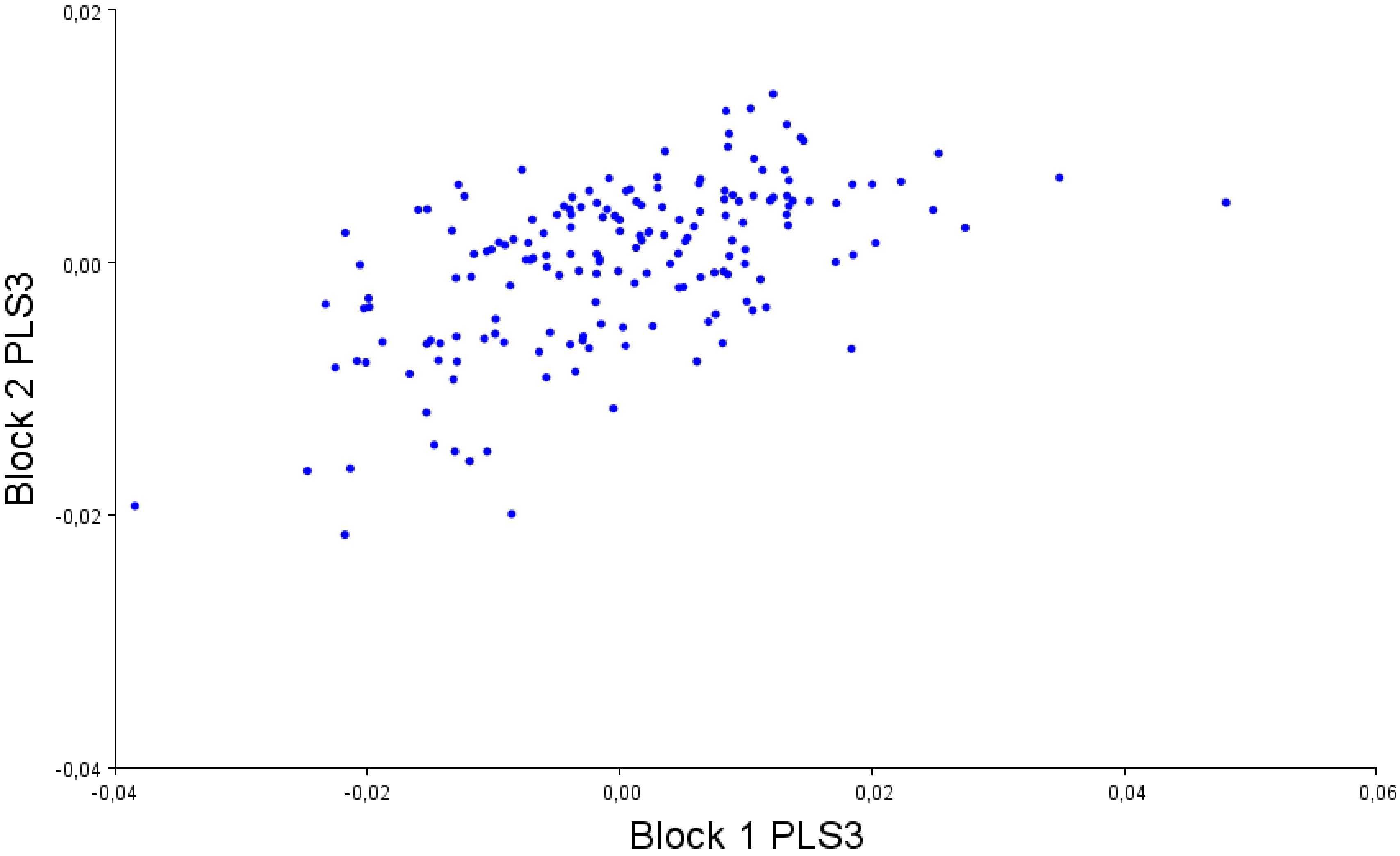
Principal Component	Variance	% variance	% cumulative variance	Broken-stick
PC 1	6,15E-04	19,30%	19,30%	2,40%
PC 2	4,11E-04	12,90%	32,30%	2,00%
PC 3	2,47E-04	7,80%	40,00%	1,80%
PC 4	2,27E-04	7,10%	47,20%	1,70%
PC 5	1,89E-04	5,90%	53,10%	1,60%
PC 6	1,53E-04	4,80%	57,90%	1,50%
PC 7	1,25E-04	3,90%	61,90%	1,40%
PC 8	1,15E-04	3,60%	65,50%	1,40%
PC 9	8,46E-05	2,70%	68,10%	1,30%
PC 10	8,44E-05	2,70%	70,80%	1,30%
PC 11	7,63E-05	2,40%	73,20%	1,30%
PC 12	6,95E-05	2,20%	75,40%	1,20%
PC 13	5,78E-05	1,80%	77,20%	1,20%
PC 14	5,16E-05	1,60%	78,80%	1,20%
PC 15	4,74E-05	1,50%	80,30%	1,10%
PC 16	4,26E-05	1,30%	81,60%	1,10%
PC 17	4,23E-05	1,30%	83,00%	1,10%
PC 18	3,84E-05	1,20%	84,20%	1,10%
PC 19	3,17E-05	1,00%	85,20%	1,00%
PC 20	2,98E-05	0,90%	86,10%	1,00%
PC 21	2,74E-05	0,90%	87,00%	1,00%
PC 22	2,46E-05	0,80%	87,80%	1,00%
PC 23	2,39E-05	0,80%	88,50%	1,00%
PC 24	2,30E-05	0,70%	89,20%	0,90%
PC 25	2,06E-05	0,60%	89,90%	0,90%
PC 26	1,98E-05	0,60%	90,50%	0,90%
PC 27	1,69E-05	0,50%	91,00%	0,90%
PC 28	1,62E-05	0,50%	91,50%	0,90%
PC 29	1,49E-05	0,50%	92,00%	0,90%
PC 30	1,38E-05	0,40%	92,40%	0,80%
PC 31	1,29E-05	0,40%	92,90%	0,80%
PC 32	1,21E-05	0,40%	93,20%	0,80%
PC 33	1,17E-05	0,40%	93,60%	0,80%
PC 34	1,10E-05	0,30%	93,90%	0,80%
PC 35	1,09E-05	0,30%	94,30%	0,80%
PC 36	9,98E-06	0,30%	94,60%	0,80%
PC 37	9,86E-06	0,30%	94,90%	0,80%
PC 38	9,10E-06	0,30%	95,20%	0,80%
PC 39	8,75E-06	0,30%	95,50%	0,70%
PC 40	8,19E-06	0,30%	95,70%	0,70%
PC 41	7,08E-06	0,20%	95,90%	0,70%
PC 42	6,88E-06	0,20%	96,20%	0,70%

Principal Component	Variance	% variance	% cumulative variance	Broken-stick
PC 43	6,76E-06	0,20%	96,40%	0,70%
PC 44	6,19E-06	0,20%	96,60%	0,70%
PC 45	5,92E-06	0,20%	96,80%	0,70%
PC 46	5,80E-06	0,20%	96,90%	0,70%
PC 47	5,12E-06	0,20%	97,10%	0,70%
PC 48	4,81E-06	0,20%	97,30%	0,70%
PC 49	4,62E-06	0,10%	97,40%	0,70%
PC 50	4,11E-06	0,10%	97,50%	0,60%


% total squared covariance
30
20
10
0
5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
PLS axis


0,02
0,00
-0,02
-0,06
-0,04
-0,02
0,00
0,02
0,04
0,06
Block 2 PLS1
Block 1 PLS1


0,02
0,00
-0,02
-0,06
-0,04
-0,02
0,00
0,02
0,04
0,06
Block 1 PLS2
Block 2 PLS2



0,02
0,00
-0,02
-0,04
-0,04
-0,02
0,00
0,02
0,04
0,06
Block 2 PLS3
Block 1 PLS3

Name	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10
Fels 1397 12	-0,0345	0,0172	0,0032	-0,0036	-0,0018	0,0020	0,0082	-0,0100	-0,0045	-0,0061
Fels 1397 14	-0,0381	0,0009	-0,0042	-0,0023	-0,0042	0,0029	0,0173	-0,0066	-0,0032	-0,0043
Fels 1441 12	-0,0342	-0,0054	0,0368	0,0074	0,0027	-0,0321	0,0061	-0,0088	0,0027	-0,0060
Fels 1441 14	-0,0547	-0,0147	0,0255	0,0009	0,0177	-0,0307	0,0026	-0,0117	0,0027	-0,0044
Fels 1583 12	-0,0282	0,0181	0,0407	0,0301	0,0068	-0,0196	0,0018	-0,0066	-0,0121	-0,0271
Fels 1583 14	-0,0382	0,0063	0,0364	0,0310	0,0139	-0,0175	0,0071	-0,0053	-0,0050	-0,0227
Fels 1586 12	0,0041	-0,0240	0,0261	-0,0095	0,0050	-0,0107	0,0078	0,0010	0,0034	0,0179
Fels 1586 14	-0,0025	-0,0347	0,0197	0,0070	-0,0001	-0,0074	0,0185	-0,0028	0,0032	0,0089
Fels 2331 12	0,0023	-0,0209	-0,0035	0,0112	0,0004	-0,0101	-0,0045	-0,0063	-0,0096	-0,0014
Fels 2331 14	-0,0047	-0,0311	-0,0102	0,0123	-0,0030	-0,0161	-0,0070	-0,0026	-0,0133	-0,0015
Fels 2485 12	-0,0179	0,0127	0,0244	-0,0033	0,0030	-0,0037	0,0016	-0,0245	-0,0103	0,0084
Fels 2485 14	-0,0225	0,0097	0,0096	0,0011	-0,0067	0,0016	0,0122	-0,0228	-0,0151	0,0085
Fels 2671 12	-0,0075	-0,0018	0,0054	-0,0028	-0,0051	-0,0084	0,0106	0,0097	-0,0249	-0,0047
Fels 2671 14	-0,0139	-0,0180	-0,0037	0,0170	-0,0023	0,0017	0,0131	0,0090	-0,0126	0,0010
Fels 3079 12	-0,0410	-0,0028	0,0128	-0,0036	-0,0172	-0,0144	0,0213	-0,0196	-0,0233	0,0041
Fels 3079 14	-0,0548	-0,0188	0,0030	-0,0027	-0,0251	-0,0155	0,0207	-0,0223	-0,0245	-0,0030
Fels 3532 12	0,0309	-0,0162	0,0139	0,0149	0,0067	0,0276	0,0055	-0,0168	-0,0117	-0,0147
Fels 3532 14	0,0320	-0,0155	0,0053	0,0098	0,0126	0,0220	-0,0061	-0,0178	-0,0067	-0,0247
Fels 4421 12	0,0353	0,0112	-0,0007	0,0054	-0,0126	-0,0078	0,0039	0,0096	-0,0042	-0,0095
Fels 4421 14	0,0305	0,0007	-0,0061	0,0106	-0,0019	-0,0048	0,0037	0,0034	-0,0042	-0,0111
Fels 4707 12	0,0110	0,0162	-0,0112	0,0080	-0,0022	-0,0197	0,0182	-0,0234	-0,0028	-0,0096
Fels 4707 14	0,0044	0,0020	-0,0326	0,0165	-0,0113	-0,0231	0,0216	-0,0207	-0,0019	-0,0131
Fels 4748 12	0,0113	-0,0044	0,0182	-0,0168	-0,0317	0,0081	0,0024	-0,0098	-0,0058	0,0063
Fels 4748 14	0,0103	-0,0090	0,0087	-0,0168	-0,0225	0,0001	-0,0053	-0,0025	-0,0055	0,0115
Fels 5627 12	0,0183	0,0433	0,0175	-0,0073	-0,0019	-0,0167	0,0055	-0,0035	-0,0186	-0,0091
Fels 5627 14	0,0161	0,0332	0,0152	0,0044	0,0036	-0,0096	0,0100	-0,0071	-0,0059	-0,0070

Name	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10
Fels 5649 12	-0,0340	-0,0107	-0,0179	-0,0079	-0,0093	0,0038	-0,0145	0,0026	-0,0155	-0,0134
Fels 5649 14	-0,0452	-0,0130	-0,0238	-0,0053	-0,0103	0,0113	-0,0089	0,0117	-0,0202	-0,0088
Fels 5730 12	0,0039	0,0112	0,0171	-0,0075	-0,0110	0,0112	0,0053	-0,0016	-0,0151	-0,0176
Fels 5730 14	-0,0106	0,0076	0,0060	-0,0044	-0,0131	0,0199	0,0066	-0,0140	-0,0161	-0,0169
Fels 6599 12	-0,0260	-0,0095	0,0106	0,0026	0,0028	-0,0116	-0,0016	-0,0005	-0,0075	-0,0070
Fels 6599 14	-0,0495	-0,0272	0,0094	-0,0011	0,0081	0,0020	-0,0033	-0,0042	-0,0077	-0,0019
Fels 6753 12	-0,0058	-0,0130	0,0394	-0,0130	-0,0063	-0,0122	0,0015	-0,0042	0,0028	-0,0116
Fels 6753 14	-0,0225	-0,0339	0,0260	-0,0089	-0,0098	-0,0064	0,0034	-0,0107	-0,0043	-0,0132
Fels 6780 12	-0,0535	0,0116	0,0155	-0,0100	-0,0266	0,0015	0,0096	0,0125	0,0043	0,0105
Fels 6780 14	-0,0594	0,0040	0,0090	-0,0070	-0,0165	-0,0005	0,0117	0,0054	-0,0021	0,0085
Fels 6976 12	-0,0015	0,0020	0,0316	-0,0048	0,0027	-0,0175	-0,0101	0,0023	-0,0128	0,0027
Fels 6976 14	-0,0172	0,0005	0,0151	-0,0016	0,0025	-0,0137	0,0019	-0,0064	-0,0251	-0,0044
Fels 7014 12	0,0229	0,0065	0,0173	-0,0077	-0,0180	-0,0050	-0,0058	-0,0242	-0,0061	-0,0065
Fels 7014 14	0,0219	-0,0035	0,0089	-0,0045	-0,0174	-0,0010	-0,0016	-0,0184	-0,0039	-0,0057
Fels 7338 12	-0,0217	-0,0047	0,0023	-0,0155	-0,0220	-0,0052	0,0028	-0,0053	-0,0129	-0,0011
Fels 7338 14	-0,0390	-0,0071	0,0033	-0,0134	-0,0003	0,0102	-0,0013	-0,0132	-0,0094	0,0066
Fels 7745 12	-0,0181	0,0163	0,0104	0,0139	-0,0080	-0,0113	-0,0145	-0,0078	0,0054	-0,0082
Fels 7745 14	-0,0260	0,0062	-0,0029	0,0259	-0,0014	-0,0117	-0,0109	-0,0127	0,0102	-0,0017
Fels 9125 12	0,0097	-0,0037	-0,0149	-0,0219	-0,0448	-0,0033	0,0052	0,0103	-0,0009	-0,0089
Fels 9125 14	-0,0083	-0,0124	-0,0225	-0,0172	-0,0355	0,0067	-0,0024	-0,0001	0,0040	-0,0102
Fels 9272 12	0,0317	0,0155	0,0161	0,0065	-0,0134	-0,0310	0,0059	0,0039	-0,0082	0,0111
Fels 9272 14	0,0130	0,0031	0,0060	0,0062	-0,0113	-0,0273	0,0009	0,0034	-0,0190	0,0073
Fels 9474 12	0,0043	0,0177	0,0202	-0,0160	-0,0069	-0,0163	-0,0157	-0,0235	0,0013	-0,0030
Fels 9474 14	0,0007	0,0045	0,0032	-0,0228	-0,0024	-0,0258	-0,0277	-0,0259	0,0071	-0,0018
Fels 9900 12	0,0478	0,0035	0,0243	-0,0143	-0,0001	-0,0096	0,0053	0,0053	-0,0222	-0,0005
Fels 9900 14	0,0235	-0,0022	0,0105	-0,0114	0,0067	-0,0085	0,0105	0,0160	-0,0113	0,0021

Name	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10
Fels F0770 12	0,0193	-0,0235	-0,0030	0,0023	0,0052	-0,0116	0,0017	-0,0094	-0,0159	-0,0008
Fels F0770 14	0,0039	-0,0295	-0,0152	0,0071	0,0124	-0,0053	0,0003	-0,0034	-0,0065	0,0076
Fels F0779 12	-0,0074	0,0220	-0,0089	0,0025	-0,0180	-0,0081	0,0055	-0,0118	-0,0115	0,0020
Fels F0779 14	-0,0209	-0,0018	-0,0217	0,0154	-0,0060	-0,0031	0,0137	-0,0037	-0,0113	0,0085
Iowa 1F 12	0,0384	0,0193	0,0124	-0,0104	0,0135	0,0037	0,0154	0,0052	-0,0026	-0,0036
Iowa 1F 14	0,0289	0,0097	0,0035	-0,0015	0,0203	0,0109	0,0099	-0,0035	-0,0047	0,0045
Iowa 1M 12	0,0186	0,0049	-0,0011	0,0015	-0,0134	-0,0129	0,0170	-0,0034	-0,0002	-0,0043
Iowa 1M 14	0,0014	-0,0057	-0,0127	0,0026	-0,0058	-0,0131	0,0194	-0,0051	0,0011	-0,0062
Iowa 10 12	-0,0331	-0,0202	0,0062	-0,0205	0,0085	0,0027	0,0401	-0,0049	-0,0105	-0,0062
Iowa 10 14	-0,0337	-0,0301	-0,0025	-0,0170	0,0132	0,0035	0,0403	-0,0042	0,0009	-0,0062
Iowa 11 12	0,0136	-0,0030	0,0109	-0,0115	-0,0101	0,0005	0,0132	0,0070	-0,0062	0,0025
Iowa 11 14	-0,0093	-0,0164	0,0061	-0,0028	-0,0043	0,0044	0,0148	0,0104	0,0011	-0,0024
Iowa 13 12	-0,0177	0,0050	0,0065	-0,0093	-0,0271	0,0190	0,0056	0,0104	-0,0006	-0,0070
Iowa 13 14	-0,0405	-0,0072	-0,0035	-0,0047	-0,0187	0,0222	0,0039	0,0066	-0,0088	-0,0049
Iowa 15 12	0,0152	-0,0264	-0,0110	0,0291	0,0060	0,0287	-0,0055	0,0113	-0,0149	0,0007
Iowa 15 14	0,0055	-0,0268	-0,0195	0,0290	0,0115	0,0283	-0,0109	0,0068	-0,0165	-0,0016
Iowa 17 12	-0,0451	0,0349	0,0164	-0,0076	-0,0276	0,0136	-0,0016	-0,0115	-0,0004	0,0020
Iowa 17 14	-0,0488	0,0309	0,0085	0,0028	-0,0322	0,0124	-0,0020	-0,0075	0,0042	0,0018
Iowa 18 12	0,0443	-0,0042	-0,0006	-0,0356	-0,0018	-0,0140	0,0249	-0,0015	0,0014	0,0067
Iowa 18 14	0,0409	-0,0117	-0,0048	-0,0323	-0,0054	-0,0130	0,0289	-0,0002	0,0023	0,0128
Iowa 19F 12	0,0190	-0,0178	0,0157	0,0042	0,0037	-0,0036	-0,0009	-0,0098	0,0031	-0,0014
Iowa 19F 14	0,0146	-0,0331	0,0052	0,0091	0,0113	-0,0075	-0,0089	-0,0123	0,0094	-0,0005
Iowa 19M 12	0,0482	0,0023	0,0126	0,0121	-0,0062	0,0111	-0,0037	-0,0017	0,0030	0,0062
Iowa 19M 14	0,0315	-0,0083	0,0005	0,0192	-0,0087	0,0105	-0,0059	-0,0083	-0,0041	0,0030
Iowa 2 12	0,0140	-0,0160	0,0130	-0,0136	-0,0012	0,0002	0,0176	-0,0075	0,0020	-0,0009
Iowa 2 14	0,0120	-0,0180	0,0080	0,0049	0,0034	0,0045	0,0166	-0,0047	0,0010	-0,0056

Name	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10
Iowa 20 12	-0,0055	-0,0337	-0,0017	0,0206	0,0118	-0,0069	-0,0174	-0,0114	-0,0175	0,0025
Iowa 20 14	-0,0179	-0,0405	-0,0062	0,0196	0,0137	-0,0107	-0,0174	-0,0086	-0,0233	0,0028
Iowa 21 12	0,0294	-0,0221	-0,0135	-0,0088	-0,0049	-0,0104	0,0222	0,0064	-0,0052	0,0040
Iowa 21 14	0,0244	-0,0322	-0,0300	-0,0001	0,0032	-0,0006	0,0118	0,0071	-0,0032	-0,0015
Iowa 22F 12	-0,0369	0,0315	0,0058	0,0188	-0,0078	0,0115	-0,0062	-0,0051	0,0099	-0,0049
Iowa 22F 14	-0,0365	0,0307	-0,0031	0,0349	-0,0045	0,0095	-0,0056	0,0003	0,0130	-0,0053
Iowa 22M 12	0,0296	0,0250	0,0056	-0,0224	-0,0117	0,0152	0,0155	-0,0028	-0,0282	0,0002
Iowa 22M 14	0,0141	0,0123	-0,0040	-0,0044	-0,0039	0,0137	0,0113	-0,0002	-0,0230	0,0071
Iowa 24M 12	-0,0019	0,0103	0,0052	-0,0022	-0,0151	-0,0201	-0,0086	0,0043	-0,0044	-0,0047
Iowa 24M 14	-0,0064	0,0185	-0,0040	0,0057	-0,0091	-0,0182	-0,0115	0,0002	0,0018	-0,0063
Iowa 28 F 12	-0,0189	0,0316	0,0212	-0,0168	-0,0004	0,0088	-0,0035	0,0043	-0,0089	0,0204
Iowa 28 F 14	-0,0265	0,0149	0,0183	-0,0201	0,0007	0,0020	0,0023	0,0086	-0,0050	0,0156
Iowa 28 M 12	-0,0085	0,0152	0,0061	0,0096	0,0103	0,0005	-0,0007	-0,0019	0,0088	0,0050
Iowa 28 M 14	-0,0038	0,0105	0,0007	0,0214	0,0082	-0,0014	-0,0015	0,0008	0,0121	0,0022
Iowa 29 F 12	0,0127	-0,0452	0,0426	0,0050	-0,0197	0,0045	0,0044	0,0160	0,0068	0,0020
Iowa 29 F 14	0,0155	-0,0493	0,0362	0,0159	-0,0140	0,0015	0,0069	0,0122	0,0082	0,0028
Iowa 3 12	0,0545	-0,0054	0,0071	0,0109	0,0024	0,0018	0,0007	-0,0140	-0,0006	0,0034
Iowa 3 14	0,0462	-0,0121	-0,0075	0,0216	0,0013	-0,0116	-0,0002	-0,0122	0,0022	0,0040
Iowa 32F 12	0,0056	-0,0246	0,0037	0,0050	-0,0003	-0,0049	0,0031	-0,0051	-0,0040	-0,0104
Iowa 32F 14	-0,0033	-0,0329	-0,0043	0,0065	-0,0023	-0,0055	-0,0020	0,0000	-0,0035	-0,0121
Iowa 33F 12	0,0081	-0,0023	0,0043	0,0103	-0,0078	0,0002	0,0090	-0,0050	-0,0024	-0,0009
Iowa 33F 14	0,0009	-0,0223	-0,0045	0,0144	-0,0019	0,0096	0,0048	-0,0121	-0,0066	-0,0009
Iowa 33M 12	-0,0039	-0,0017	0,0003	0,0039	0,0152	0,0068	0,0135	-0,0012	0,0067	-0,0025
Iowa 33M 14	-0,0086	-0,0024	-0,0100	0,0177	0,0105	0,0027	0,0155	0,0023	0,0123	-0,0084
Iowa 34F 12	0,0185	0,0265	0,0382	0,0181	0,0241	0,0014	0,0069	-0,0114	-0,0064	0,0217
Iowa 34F 14	0,0208	0,0214	0,0338	0,0185	0,0258	-0,0032	0,0058	-0,0108	0,0011	0,0185

Name	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10
Iowa 35M 12	0,0017	0,0368	-0,0013	0,0074	-0,0166	0,0106	0,0076	0,0169	-0,0003	0,0135
Iowa 35M 14	0,0026	0,0251	-0,0129	-0,0030	-0,0155	0,0137	0,0122	0,0184	0,0031	0,0047
Iowa 40M 12	0,0234	-0,0107	-0,0136	0,0245	-0,0116	-0,0069	0,0074	0,0025	0,0109	-0,0026
Iowa 40M 14	0,0079	-0,0076	-0,0254	0,0234	-0,0054	-0,0058	0,0053	0,0031	0,0109	-0,0068
Iowa 41M 12	-0,0064	0,0051	-0,0116	-0,0135	0,0035	0,0223	-0,0010	-0,0148	-0,0024	-0,0001
Iowa 41M 14	-0,0154	-0,0060	-0,0237	-0,0075	0,0106	0,0214	0,0044	-0,0144	-0,0011	0,0021
Iowa 43F 12	-0,0328	0,0113	0,0191	0,0000	0,0044	0,0024	-0,0058	-0,0223	0,0095	-0,0016
Iowa 43F 14	-0,0380	0,0024	0,0125	0,0021	0,0089	0,0026	-0,0050	-0,0272	0,0143	0,0076
Iowa 44F 12	-0,0185	-0,0259	0,0126	0,0074	-0,0093	0,0069	-0,0041	-0,0129	0,0032	0,0128
Iowa 44F 14	-0,0220	-0,0361	0,0057	0,0173	-0,0100	0,0092	-0,0053	-0,0145	0,0058	0,0101
Iowa 46F 12	0,0076	0,0290	0,0041	0,0055	0,0056	0,0046	0,0059	0,0019	0,0066	0,0112
Iowa 46F 14	0,0037	0,0176	-0,0060	0,0121	0,0059	0,0150	0,0118	0,0024	0,0038	0,0093
Iowa 47F 12	0,0105	-0,0068	0,0233	0,0047	-0,0103	0,0014	0,0024	0,0048	0,0045	0,0063
Iowa 47F 14	-0,0054	-0,0212	0,0148	0,0061	-0,0135	0,0057	0,0005	0,0024	0,0049	0,0066
Iowa 49F 12	-0,0443	0,0066	0,0057	0,0007	-0,0102	0,0187	-0,0014	-0,0199	0,0096	0,0192
Iowa 49F 14	-0,0424	0,0051	-0,0022	0,0085	-0,0056	0,0167	0,0008	-0,0229	0,0107	0,0176
Iowa 50F 12	0,0107	0,0065	0,0150	0,0188	-0,0327	-0,0059	-0,0078	0,0067	0,0021	0,0026
Iowa 50F 14	-0,0019	0,0035	0,0095	0,0144	-0,0369	-0,0042	-0,0054	0,0037	0,0041	-0,0005
Iowa 50M 12	-0,0314	-0,0119	-0,0126	-0,0018	-0,0059	0,0006	0,0019	-0,0015	0,0007	0,0069
Iowa 50M 14	-0,0401	-0,0259	-0,0247	0,0076	-0,0090	0,0039	0,0087	0,0043	0,0072	0,0054
Iowa 51M 12	0,0062	-0,0309	0,0117	-0,0032	0,0074	-0,0051	-0,0186	-0,0085	0,0046	0,0013
Iowa 51M 14	0,0003	-0,0359	0,0036	0,0048	-0,0004	-0,0035	-0,0073	-0,0030	0,0064	-0,0023
Iowa 52F 12	-0,0023	-0,0081	0,0264	0,0225	-0,0056	0,0195	0,0013	0,0014	-0,0029	0,0075
Iowa 52F 14	-0,0037	-0,0172	0,0232	0,0222	-0,0068	0,0201	-0,0015	0,0008	-0,0056	0,0035
Iowa 53M 12	-0,0105	-0,0028	-0,0214	0,0123	0,0018	0,0205	0,0097	0,0008	-0,0024	0,0209
Iowa 53M 14	-0,0117	-0,0166	-0,0324	0,0314	0,0081	0,0201	0,0102	-0,0019	-0,0022	0,0213

Name	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10
Iowa 59F 12	0,0434	-0,0334	-0,0130	-0,0131	-0,0129	-0,0002	0,0061	0,0014	-0,0005	0,0025
Iowa 59F 14	0,0334	-0,0413	-0,0180	-0,0128	-0,0134	0,0038	0,0083	-0,0001	-0,0034	0,0033
Iowa 6 12	0,0079	-0,0529	-0,0075	-0,0083	-0,0070	0,0088	-0,0045	0,0094	-0,0186	0,0060
Iowa 6 14	-0,0052	-0,0500	-0,0149	0,0003	-0,0013	0,0052	-0,0127	0,0103	-0,0159	-0,0009
Iowa 61F 12	-0,0122	0,0036	0,0150	0,0230	0,0035	-0,0187	-0,0005	0,0166	0,0061	-0,0070
Iowa 61F 14	-0,0220	0,0030	0,0139	0,0288	0,0081	-0,0055	0,0016	0,0171	0,0052	-0,0033
Iowa 64M 12	0,0363	-0,0014	0,0012	0,0118	-0,0098	0,0066	0,0144	0,0125	0,0124	0,0084
Iowa 64M 14	0,0230	-0,0219	-0,0156	0,0198	0,0023	0,0047	0,0105	0,0127	0,0183	0,0017
Iowa 65M 12	-0,0013	-0,0122	-0,0040	-0,0111	-0,0201	0,0128	-0,0100	0,0129	0,0050	-0,0032
Iowa 65M 14	-0,0189	-0,0241	-0,0057	-0,0078	-0,0190	0,0130	-0,0113	0,0121	0,0003	-0,0089
Iowa 66F 12	-0,0172	0,0094	0,0257	-0,0054	0,0094	0,0114	-0,0130	-0,0116	0,0071	-0,0005
Iowa 66F 14	-0,0245	0,0042	0,0190	0,0152	-0,0001	0,0068	-0,0024	-0,0072	0,0114	0,0004
Iowa 66M 12	0,0232	0,0304	-0,0045	0,0011	0,0023	0,0106	0,0068	0,0082	-0,0032	0,0096
Iowa 66M 14	0,0173	0,0226	-0,0156	0,0002	0,0049	0,0110	0,0052	0,0089	-0,0063	-0,0010
Iowa 67M 12	-0,0076	0,0059	0,0275	0,0082	0,0075	-0,0149	0,0064	0,0090	0,0016	0,0072
Iowa 67M 14	-0,0232	-0,0186	0,0173	0,0105	0,0170	-0,0095	0,0062	0,0121	-0,0008	0,0065
Iowa 68M 12	0,0074	-0,0077	0,0250	0,0089	0,0093	-0,0092	0,0073	0,0182	0,0014	0,0187
Iowa 68M 14	0,0094	-0,0237	0,0096	0,0082	0,0183	-0,0024	-0,0019	0,0109	0,0084	0,0174
Iowa 70F 12	0,0202	-0,0231	0,0180	-0,0071	-0,0140	0,0064	-0,0092	0,0027	-0,0023	0,0153
Iowa 70F 14	0,0092	-0,0235	0,0104	-0,0079	-0,0040	0,0074	-0,0188	-0,0032	-0,0033	0,0217
Iowa 72F 12	0,0217	-0,0509	0,0129	0,0031	0,0210	-0,0099	-0,0126	-0,0024	0,0008	0,0085
Iowa 72F 14	0,0110	-0,0605	0,0042	0,0050	0,0243	-0,0171	-0,0206	-0,0001	-0,0103	0,0119
Iowa 73M 12	-0,0189	-0,0108	-0,0016	-0,0204	0,0082	-0,0055	-0,0030	-0,0150	-0,0008	0,0138
Iowa 73M 14	-0,0200	-0,0193	-0,0172	-0,0187	0,0075	-0,0110	0,0030	-0,0074	0,0034	0,0026
Iowa 74M 12	0,0248	-0,0160	0,0240	-0,0135	0,0126	0,0031	0,0025	0,0018	-0,0026	0,0134
Iowa 74M 14	0,0087	-0,0181	0,0123	-0,0025	0,0105	0,0031	0,0057	0,0001	0,0001	0,0129

Name	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10
Iowa 77M 12	0,0267	0,0134	0,0172	0,0122	0,0109	0,0135	0,0037	-0,0034	0,0082	0,0108
Iowa 77M 14	0,0118	0,0021	0,0100	0,0110	0,0174	0,0233	0,0114	-0,0025	0,0083	0,0061
Iowa 9 12	0,0355	0,0053	-0,0199	0,0069	-0,0053	-0,0121	-0,0031	0,0003	-0,0085	0,0086
Iowa 9 14	0,0293	-0,0009	-0,0249	0,0081	-0,0003	-0,0052	0,0041	-0,0048	-0,0099	0,0093
Oregon 123-1F 12	0,0419	0,0197	-0,0058	-0,0001	0,0074	0,0007	-0,0115	-0,0243	-0,0067	0,0142
Oregon 123-1F 14	0,0405	0,0073	-0,0174	0,0020	0,0060	-0,0010	-0,0097	-0,0217	-0,0009	0,0176
Oregon 123-2F 12	0,0250	0,0405	0,0217	0,0147	-0,0136	0,0202	0,0084	-0,0086	0,0053	0,0104
Oregon 123-2F 14	0,0166	0,0311	0,0079	0,0237	-0,0164	0,0105	0,0063	-0,0090	0,0068	0,0085
Oregon 144M 12	-0,0047	0,0050	-0,0132	-0,0204	-0,0144	-0,0043	-0,0153	0,0009	0,0087	0,0166
Oregon 144M 14	-0,0233	-0,0020	-0,0184	-0,0109	-0,0218	0,0008	-0,0055	-0,0029	0,0012	0,0101
Oregon 153M 12	0,0418	-0,0010	-0,0120	-0,0081	0,0016	0,0040	0,0041	-0,0192	0,0080	-0,0003
Oregon 153M 14	0,0238	0,0015	-0,0260	0,0045	0,0124	0,0107	0,0025	-0,0109	0,0016	-0,0021
Oregon 15F 12	-0,0309	0,0230	0,0005	-0,0123	-0,0092	-0,0087	-0,0026	0,0062	-0,0126	-0,0148
Oregon 15F 14	-0,0342	0,0072	-0,0099	-0,0009	-0,0051	-0,0116	0,0000	0,0047	-0,0120	-0,0158
Oregon 179M 12	-0,0311	0,0576	-0,0231	-0,0058	0,0068	0,0041	0,0000	0,0043	-0,0039	-0,0011
Oregon 179M 14	-0,0360	0,0500	-0,0335	0,0044	0,0075	0,0067	-0,0035	0,0053	-0,0009	-0,0027
Oregon 180F 12	0,0038	0,0393	0,0037	-0,0013	0,0006	0,0004	-0,0059	-0,0110	0,0024	0,0063
Oregon 180F 14	0,0013	0,0309	-0,0113	0,0011	-0,0012	0,0032	-0,0098	-0,0084	0,0046	0,0101
Oregon 198F 12	-0,0082	0,0153	-0,0105	0,0053	-0,0145	0,0083	0,0048	0,0124	-0,0094	0,0060
Oregon 198F 14	-0,0313	0,0033	-0,0228	0,0200	-0,0142	0,0152	0,0087	0,0154	-0,0109	0,0054
Oregon 222 12	0,0074	-0,0125	0,0173	0,0177	0,0037	0,0042	0,0142	0,0042	0,0055	-0,0047
Oregon 222 14	-0,0139	-0,0177	0,0017	0,0242	0,0023	-0,0018	0,0174	-0,0026	0,0022	-0,0129
Oregon 226M 12	0,0034	0,0084	0,0015	-0,0024	0,0149	-0,0279	-0,0306	0,0027	0,0032	-0,0014
Oregon 226M 14	-0,0067	-0,0065	-0,0128	0,0143	0,0055	-0,0366	-0,0278	0,0147	0,0119	-0,0010
Oregon 241-2F 12	-0,0103	-0,0142	-0,0041	0,0137	-0,0218	0,0026	-0,0114	0,0058	0,0033	0,0028
Oregon 241-2F 14	-0,0291	-0,0233	-0,0112	0,0197	-0,0268	0,0036	-0,0133	0,0055	0,0009	-0,0025

Name	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10
Oregon 242F 12	0,0257	0,0261	-0,0224	0,0025	0,0086	-0,0126	-0,0382	0,0051	-0,0151	-0,0033
Oregon 242F 14	0,0172	0,0195	-0,0316	-0,0029	0,0125	-0,0064	-0,0398	-0,0027	-0,0161	-0,0035
Oregon 247F 12	0,0179	0,0340	-0,0045	-0,0015	0,0020	0,0168	0,0136	-0,0107	-0,0063	0,0044
Oregon 247F 14	0,0154	0,0243	-0,0119	0,0081	0,0004	0,0128	0,0145	-0,0075	0,0005	0,0099
Oregon 248F 12	0,0324	0,0057	-0,0086	-0,0146	0,0010	-0,0231	-0,0118	-0,0004	0,0000	0,0082
Oregon 248F 14	0,0283	-0,0058	-0,0217	-0,0063	0,0063	-0,0194	-0,0067	-0,0001	-0,0020	0,0118
Oregon 275F 12	-0,0171	-0,0029	-0,0241	-0,0107	-0,0021	-0,0010	0,0015	-0,0089	0,0095	0,0010
Oregon 275F 14	-0,0202	-0,0062	-0,0274	-0,0025	0,0045	0,0034	-0,0001	-0,0106	0,0133	0,0048
Oregon 290-1M 12	-0,0117	0,0028	0,0194	-0,0197	0,0198	0,0139	-0,0289	-0,0087	-0,0050	0,0127
Oregon 290-1M 14	-0,0249	-0,0139	0,0108	-0,0200	0,0169	0,0153	-0,0315	-0,0126	-0,0064	0,0071
Oregon 295M 12	0,0025	-0,0064	-0,0043	-0,0077	-0,0285	-0,0028	0,0077	-0,0214	0,0110	-0,0016
Oregon 295M 14	-0,0136	-0,0288	-0,0165	-0,0035	-0,0266	-0,0030	0,0103	-0,0212	0,0179	-0,0048
Oregon 297F 12	0,0381	0,0412	-0,0156	-0,0007	-0,0089	0,0189	-0,0157	0,0021	0,0028	-0,0026
Oregon 297F 14	0,0341	0,0327	-0,0276	0,0082	-0,0025	0,0139	-0,0165	0,0025	-0,0044	-0,0013
Oregon 301F 12	-0,0157	0,0002	-0,0004	0,0099	0,0115	-0,0046	-0,0103	-0,0020	0,0126	-0,0001
Oregon 301F 14	-0,0145	-0,0117	-0,0002	0,0211	0,0021	0,0054	-0,0001	-0,0018	0,0150	-0,0022
Oregon 305F 12	0,0378	0,0143	0,0050	-0,0296	-0,0001	0,0225	-0,0053	-0,0240	0,0150	0,0108
Oregon 305F 14	0,0337	-0,0062	-0,0020	-0,0230	-0,0084	0,0210	0,0036	-0,0193	0,0120	0,0091
Oregon 33M 12	-0,0262	0,0258	0,0011	-0,0136	-0,0066	-0,0010	-0,0076	0,0082	0,0025	-0,0057
Oregon 33M 14	-0,0283	0,0044	-0,0127	-0,0031	-0,0090	-0,0080	-0,0011	0,0099	-0,0064	-0,0124
Oregon 79F 12	-0,0025	0,0457	0,0041	0,0331	-0,0170	0,0074	0,0010	0,0039	0,0171	0,0004
Oregon 79F 14	-0,0129	0,0405	-0,0039	0,0377	-0,0238	0,0055	-0,0002	0,0066	0,0104	-0,0010
Oregon 89-1M 12	0,0189	0,0012	0,0161	0,0097	-0,0073	-0,0051	-0,0067	-0,0014	0,0186	0,0086
Oregon 89-1M 14	0,0119	-0,0058	0,0041	0,0087	-0,0069	-0,0042	-0,0096	-0,0040	0,0196	0,0013
Oregon 89-2M 12	0,0167	0,0033	0,0034	0,0066	-0,0051	-0,0194	-0,0112	-0,0140	0,0014	0,0039
Oregon 89-2M 14	0,0058	-0,0059	-0,0135	0,0069	-0,0086	-0,0250	-0,0092	-0,0113	0,0030	-0,0016

Name	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10
Burlington 25 F 12	0,0031	0,0068	0,0112	-0,0018	-0,0311	0,0020	-0,0023	0,0181	0,0153	-0,0028
Burlington 25 F 14	-0,0014	0,0051	0,0033	0,0063	-0,0216	-0,0020	-0,0052	0,0150	0,0105	-0,0020
Burlington 230 F 12	-0,0159	-0,0290	-0,0005	-0,0405	0,0323	0,0231	0,0083	-0,0056	0,0117	0,0062
Burlington 230 F 14	-0,0259	-0,0334	-0,0065	-0,0362	0,0330	0,0327	0,0112	-0,0067	0,0073	0,0059
Burlington 153 F 12	-0,0147	-0,0411	-0,0016	0,0154	-0,0053	0,0021	-0,0006	0,0131	0,0094	0,0026
Burlington 153 F 14	-0,0240	-0,0411	-0,0083	0,0230	-0,0039	0,0053	-0,0059	0,0100	0,0056	0,0033
Burlington 163 F 12	-0,0081	0,0256	0,0227	0,0049	-0,0050	0,0055	-0,0113	0,0153	-0,0060	-0,0089
Burlington 163 F 14	-0,0205	0,0220	0,0172	0,0097	-0,0006	0,0048	-0,0099	0,0156	-0,0019	-0,0100
Burlington 166 M 12	0,0148	0,0011	-0,0110	-0,0193	0,0032	-0,0043	0,0054	0,0191	-0,0009	-0,0130
Burlington 166 M 14	0,0069	-0,0057	-0,0229	-0,0052	0,0063	-0,0057	0,0037	0,0162	0,0021	-0,0161
Burlington 183 M 12	0,0152	0,0070	0,0180	-0,0023	0,0004	-0,0217	0,0095	0,0177	-0,0023	0,0049
Burlington 183 M 14	0,0115	0,0080	0,0157	0,0028	0,0044	-0,0291	0,0080	0,0201	-0,0003	0,0078
Burlington 185 M 12	-0,0262	0,0036	-0,0171	-0,0110	0,0046	0,0022	-0,0123	0,0126	-0,0020	-0,0075
Burlington 185 M 14	-0,0252	-0,0106	-0,0285	-0,0101	0,0083	-0,0009	-0,0084	0,0093	0,0013	-0,0136
Burlington 186 M 12	0,0003	-0,0106	0,0083	0,0096	-0,0375	-0,0025	-0,0106	-0,0011	0,0094	0,0042
Burlington 186 M 14	-0,0127	-0,0092	-0,0038	0,0234	-0,0387	-0,0063	-0,0094	0,0040	0,0059	0,0008
Burlington 188 F 12	-0,0043	-0,0126	0,0039	0,0318	0,0207	0,0138	-0,0032	0,0109	0,0035	-0,0134
Burlington 188 F 14	-0,0116	-0,0206	0,0061	0,0297	0,0244	0,0188	-0,0015	0,0092	0,0045	-0,0173
Burlington 198 F 12	-0,0040	-0,0110	-0,0009	-0,0187	0,0229	0,0003	0,0038	0,0214	0,0022	0,0084
Burlington 198 F 14	-0,0104	-0,0151	-0,0026	-0,0117	0,0200	-0,0003	0,0069	0,0179	0,0033	0,0072
Burlington 206 M 12	-0,0484	0,0230	-0,0082	-0,0253	-0,0032	0,0067	0,0004	0,0033	0,0160	0,0110
Burlington 206 M 14	-0,0509	0,0229	-0,0256	-0,0211	-0,0068	-0,0051	-0,0004	0,0088	0,0184	0,0060
Burlington 208 F 12	-0,0316	-0,0034	0,0145	-0,0009	0,0195	-0,0026	0,0189	0,0011	-0,0078	-0,0085
Burlington 208 F 14	-0,0377	-0,0172	0,0065	-0,0010	0,0226	-0,0002	0,0157	-0,0012	-0,0072	-0,0139
Burlington 231 M 12	0,0417	0,0199	0,0009	-0,0244	0,0094	0,0268	0,0027	0,0100	-0,0067	-0,0115
Burlington 231 M 14	0,0401	0,0085	-0,0181	-0,0144	0,0104	0,0222	0,0012	0,0101	-0,0044	-0,0130

Name	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10
Burlington 245 F 12	-0,0290	0,0111	0,0114	0,0068	0,0160	-0,0079	-0,0113	-0,0042	0,0044	-0,0128
Burlington 245 F 14	-0,0362	0,0129	0,0106	0,0104	0,0193	-0,0078	-0,0047	-0,0033	-0,0029	-0,0103
Burlington 257 F 12	0,0267	0,0239	-0,0126	0,0014	0,0109	-0,0208	0,0003	-0,0038	-0,0231	0,0036
Burlington 257 F 14	0,0238	0,0280	-0,0217	0,0019	0,0098	-0,0166	-0,0011	-0,0067	-0,0211	0,0057
Burlington 289 M 12	-0,0280	0,0146	-0,0252	-0,0108	0,0025	-0,0116	-0,0037	-0,0069	0,0010	0,0089
Burlington 289 M 14	-0,0391	0,0014	-0,0341	-0,0062	-0,0012	-0,0086	0,0001	-0,0060	0,0048	0,0052
Burlington 295 M 12	0,0075	-0,0011	0,0040	-0,0012	0,0044	0,0274	0,0002	-0,0020	-0,0044	-0,0177
Burlington 295 M 14	0,0057	-0,0030	-0,0036	0,0152	0,0036	0,0240	0,0030	-0,0007	-0,0051	-0,0213
Burlington 321 F 12	0,0364	0,0095	-0,0117	-0,0088	-0,0088	-0,0293	0,0056	0,0122	0,0081	0,0068
Burlington 321 F 14	0,0280	0,0065	-0,0180	-0,0144	-0,0017	-0,0193	-0,0001	0,0063	0,0044	0,0011
Burlington 355 12	-0,0387	0,0114	-0,0162	-0,0080	0,0035	-0,0048	-0,0072	0,0096	-0,0099	0,0100
Burlington 355 14	-0,0501	0,0029	-0,0261	0,0037	0,0026	-0,0019	-0,0039	0,0073	-0,0063	0,0050
Burlington 357 M 12	0,0202	0,0249	0,0104	-0,0106	-0,0188	0,0281	-0,0079	0,0017	-0,0128	-0,0125
Burlington 357 M 14	0,0057	0,0057	-0,0154	-0,0050	-0,0094	0,0212	-0,0096	0,0096	-0,0129	-0,0103
Burlington 366 M 12	0,0243	-0,0052	-0,0327	-0,0183	-0,0168	-0,0181	-0,0053	-0,0010	0,0079	0,0072
Burlington 366 M 14	0,0184	-0,0071	-0,0381	-0,0221	-0,0124	-0,0167	-0,0053	-0,0043	0,0083	0,0020
Burlington 391 F 12	0,0101	0,0061	0,0086	0,0076	0,0068	0,0003	-0,0085	-0,0010	-0,0101	0,0179
Burlington 391 F 14	-0,0043	-0,0008	0,0034	0,0182	-0,0039	0,0042	-0,0026	0,0055	-0,0080	0,0133
Burlington 392 M 12	0,0132	-0,0046	0,0045	-0,0104	0,0064	0,0018	-0,0003	0,0129	0,0085	0,0005
Burlington 392 M 14	0,0008	-0,0035	-0,0039	-0,0058	0,0088	-0,0013	0,0070	0,0127	0,0098	-0,0024
Burlington 421 F 12	0,0084	-0,0209	0,0218	-0,0125	-0,0080	0,0099	-0,0320	0,0088	-0,0043	0,0089
Burlington 421 F 14	0,0006	-0,0271	0,0197	-0,0158	0,0005	0,0086	-0,0326	0,0035	-0,0038	0,0139
Burlington 482 F 12	0,0014	0,0188	-0,0022	0,0024	0,0436	0,0071	-0,0032	0,0038	0,0118	0,0017
Burlington 482 F 14	-0,0008	0,0168	-0,0039	0,0109	0,0482	0,0071	-0,0029	0,0021	0,0107	-0,0031
Burlington 487 F 12	-0,0171	-0,0066	-0,0188	-0,0136	0,0043	-0,0022	-0,0059	0,0047	-0,0041	-0,0021
Burlington 487 F 14	-0,0285	-0,0189	-0,0232	-0,0051	0,0076	0,0012	-0,0078	0,0042	-0,0043	-0,0031

Name	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10
Burlington 532 F 12	0,0122	-0,0282	-0,0071	-0,0292	0,0020	0,0052	-0,0018	0,0050	0,0115	0,0036
Burlington 532 F 14	0,0072	-0,0407	-0,0088	-0,0299	-0,0024	0,0106	-0,0043	0,0043	0,0094	0,0010
Burlington 544 M 12	0,0368	-0,0054	0,0080	-0,0038	0,0045	-0,0042	-0,0012	0,0097	-0,0001	-0,0152
Burlington 544 M 14	0,0292	-0,0124	0,0005	0,0035	0,0045	-0,0040	0,0013	0,0092	0,0001	-0,0219
Burlington 595 F 12	-0,0245	0,0061	0,0086	0,0150	-0,0078	-0,0010	-0,0231	-0,0030	0,0003	-0,0085
Burlington 595 F 14	-0,0291	-0,0020	-0,0006	0,0202	-0,0044	0,0057	-0,0185	-0,0058	0,0039	-0,0035
Burlington 602 F 12	-0,0129	0,0180	0,0286	-0,0237	0,0254	0,0020	-0,0138	0,0018	0,0069	-0,0020
Burlington 602 F 14	-0,0285	0,0154	0,0223	-0,0189	0,0260	0,0006	-0,0164	-0,0059	0,0072	-0,0024
Burlington 608 F 12	0,0475	-0,0152	0,0241	-0,0123	0,0022	0,0036	0,0010	-0,0001	0,0069	-0,0130
Burlington 608 F 14	0,0381	-0,0294	0,0224	0,0010	-0,0021	0,0098	0,0062	-0,0078	0,0094	-0,0134
Burlington 612 M 12	0,0291	0,0115	0,0112	-0,0131	0,0153	-0,0027	0,0120	0,0032	0,0069	0,0010
Burlington 612 M 14	0,0232	0,0069	0,0007	0,0030	0,0169	-0,0046	0,0125	0,0013	0,0077	0,0041
Burlington 619 F 12	0,0026	-0,0091	0,0093	-0,0086	0,0085	0,0047	0,0128	-0,0100	0,0069	-0,0060
Burlington 619 F 14	-0,0066	-0,0128	0,0017	0,0001	0,0082	0,0017	0,0118	-0,0073	0,0074	-0,0071
Burlington 631 F 12	-0,0185	-0,0027	-0,0133	-0,0076	0,0072	-0,0046	0,0011	-0,0078	0,0010	-0,0044
Burlington 631 F 14	-0,0277	-0,0175	-0,0229	-0,0038	0,0085	-0,0063	0,0036	-0,0127	0,0026	-0,0104
Burlington 636 M 12	0,0095	-0,0191	0,0353	-0,0240	0,0130	0,0083	-0,0060	0,0263	0,0085	-0,0073
Burlington 636 M 14	0,0049	-0,0285	0,0232	-0,0153	0,0159	0,0017	-0,0130	0,0262	0,0111	-0,0067
Burlington 706 M 12	0,0172	0,0112	0,0075	-0,0352	-0,0069	0,0001	0,0043	0,0191	-0,0077	0,0007
Burlington 706 M 14	0,0164	0,0024	0,0022	-0,0227	-0,0058	0,0014	0,0056	0,0193	-0,0047	-0,0001
Burlington 717 F 12	-0,0353	0,0640	0,0263	-0,0032	0,0044	-0,0179	0,0077	0,0184	0,0086	0,0053
Burlington 717 F 14	-0,0407	0,0486	0,0171	-0,0002	0,0058	-0,0194	0,0048	0,0123	0,0101	-0,0003
Burlington 735 F 12	0,0097	0,0277	0,0099	0,0075	0,0026	0,0007	0,0030	0,0057	0,0094	-0,0039
Burlington 735 F 14	0,0031	0,0292	0,0014	0,0152	0,0070	0,0020	0,0020	0,0088	0,0139	-0,0042
Burlington 740 M 12	-0,0220	0,0009	-0,0270	-0,0272	0,0171	-0,0073	0,0081	0,0078	-0,0056	0,0089
Burlington 740 M 14	-0,0356	-0,0028	-0,0347	-0,0296	0,0305	-0,0139	0,0027	-0,0004	-0,0052	-0,0035

Name	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10
Burlington 637 M 12	0,0063	0,0404	0,0037	-0,0249	-0,0007	0,0086	-0,0062	-0,0084	0,0154	-0,0170
Burlington 637 M 14	0,0016	0,0333	-0,0190	-0,0188	0,0058	0,0009	-0,0081	-0,0104	0,0193	-0,0233
Burlington 742 M 12	0,0320	0,0067	-0,0039	-0,0087	0,0093	-0,0018	0,0048	-0,0015	0,0005	0,0021
Burlington 742 M 14	0,0332	0,0002	-0,0109	0,0019	0,0094	-0,0067	0,0047	0,0013	0,0066	0,0000
Burlington 763 M 12	-0,0263	0,0042	-0,0107	0,0077	0,0022	-0,0050	-0,0043	-0,0106	-0,0090	0,0027
Burlington 763 M 14	-0,0296	-0,0151	-0,0282	0,0190	-0,0044	-0,0134	-0,0027	-0,0029	-0,0036	0,0037
Burlington 847 F 12	0,0128	0,0138	-0,0152	-0,0155	-0,0146	-0,0209	0,0147	-0,0081	0,0095	-0,0052
Burlington 847 F 14	0,0118	0,0005	-0,0236	0,0043	-0,0166	-0,0180	0,0148	-0,0104	0,0107	-0,0005
Burlington 848 F 12	0,0257	0,0069	-0,0074	-0,0119	-0,0106	-0,0176	0,0101	-0,0073	0,0073	-0,0094
Burlington 848 F 14	0,0020	0,0008	-0,0152	0,0035	-0,0212	-0,0013	0,0095	-0,0052	0,0153	-0,0049
Burlington 855 F 12	0,0029	0,0251	0,0021	-0,0076	0,0269	-0,0120	0,0171	0,0188	0,0023	-0,0034
Burlington 855 F 14	-0,0018	0,0077	-0,0056	-0,0142	0,0178	-0,0293	0,0176	0,0254	0,0098	-0,0041
Burlington 863 M 12	-0,0288	0,0256	-0,0024	-0,0217	0,0211	0,0089	0,0046	-0,0039	-0,0001	-0,0041
Burlington 863 M 14	-0,0439	0,0110	-0,0175	-0,0059	0,0149	0,0106	0,0087	0,0006	0,0024	-0,0030
Burlington 865 M 12	0,0275	0,0203	0,0050	0,0264	-0,0049	0,0143	-0,0047	-0,0020	-0,0126	-0,0007
Burlington 865 M 14	0,0165	0,0101	-0,0069	0,0355	0,0026	0,0168	-0,0043	-0,0001	-0,0093	-0,0044
Burlington 871 M 12	0,0240	0,0265	0,0017	0,0008	-0,0102	-0,0170	-0,0028	0,0089	-0,0080	0,0125
Burlington 871 M 14	0,0223	0,0260	-0,0154	0,0160	-0,0058	-0,0148	-0,0030	0,0134	-0,0061	0,0123
Burlington 914 F 12	-0,0466	-0,0260	0,0285	-0,0414	-0,0225	0,0042	-0,0137	0,0202	0,0040	-0,0048
Burlington 914 F 14	-0,0510	-0,0406	0,0195	-0,0359	-0,0250	-0,0001	-0,0054	0,0255	0,0077	-0,0039
Burlington 920 F 12	0,0267	-0,0124	0,0106	-0,0016	-0,0135	-0,0090	-0,0023	0,0151	0,0083	0,0042
Burlington 920 F 14	0,0260	-0,0206	0,0030	-0,0046	-0,0095	-0,0111	-0,0049	0,0155	0,0047	0,0015
Burlington 948 F 12	0,0189	-0,0211	-0,0060	0,0172	-0,0022	0,0140	0,0119	-0,0012	-0,0013	0,0013
Burlington 948 F 14	0,0268	-0,0282	-0,0135	0,0175	0,0041	0,0109	0,0119	-0,0013	0,0028	0,0006
Burlington 1024 F 12	0,0282	0,0111	0,0101	0,0023	0,0001	-0,0070	-0,0156	-0,0093	0,0009	-0,0137
Burlington 1024 F 14	0,0265	-0,0049	0,0019	0,0071	0,0007	-0,0074	-0,0136	-0,0052	0,0032	-0,0142

Name	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10
Burlington 1068 M 12	-0,0168	0,0152	-0,0065	0,0070	0,0196	-0,0154	0,0229	-0,0103	0,0056	0,0045
Burlington 1068 M 14	-0,0214	0,0119	-0,0104	0,0082	0,0263	-0,0184	0,0213	-0,0119	0,0081	0,0016
Burlington 1085 M 12	0,0099	0,0012	-0,0159	0,0132	0,0074	0,0092	-0,0193	0,0017	-0,0030	0,0101
Burlington 1085 M 14	0,0098	-0,0051	-0,0209	0,0144	0,0156	0,0059	-0,0221	0,0039	-0,0034	0,0055
Burlington 1351 M 12	0,0293	0,0054	0,0067	0,0007	-0,0010	0,0115	0,0020	-0,0055	0,0144	-0,0237
Burlington 1351 M 14	0,0230	-0,0050	-0,0051	0,0112	0,0014	0,0085	0,0034	-0,0045	0,0225	-0,0277
Burlington 1366 F 12	0,0404	0,0087	-0,0106	-0,0168	0,0013	0,0033	-0,0084	-0,0023	0,0111	-0,0040
Burlington 1366 F 14	0,0397	0,0033	-0,0232	-0,0042	-0,0020	-0,0059	-0,0045	0,0012	0,0132	-0,0103
Burlington 1378 M 12	-0,0012	0,0029	-0,0022	-0,0218	0,0111	0,0050	-0,0085	0,0052	0,0124	0,0007
Burlington 1378 M 14	-0,0062	-0,0028	-0,0029	-0,0201	0,0148	-0,0003	-0,0084	0,0034	0,0124	-0,0063
Burlington 1391 F 12	0,0032	0,0212	-0,0078	-0,0036	-0,0014	-0,0012	0,0052	0,0121	0,0020	0,0171
Burlington 1391 F 14	0,0029	0,0135	-0,0188	0,0032	0,0007	-0,0017	0,0050	0,0111	0,0056	0,0162
Burlington 1392 F 12	-0,0105	0,0040	-0,0059	0,0194	0,0185	-0,0115	-0,0005	0,0151	-0,0031	0,0123
Burlington 1392 F 14	-0,0079	-0,0073	-0,0149	0,0309	0,0185	-0,0119	-0,0014	0,0144	-0,0006	0,0102
Burlington 2502 F 12	-0,0063	-0,0017	0,0113	-0,0330	0,0198	0,0080	-0,0024	-0,0103	-0,0045	-0,0119
Burlington 2502 F 14	-0,0141	0,0026	0,0079	-0,0293	0,0164	0,0121	0,0019	-0,0124	0,0025	-0,0094
Burlington 2519 F 12	-0,0227	0,0128	-0,0027	0,0162	-0,0003	0,0115	0,0067	0,0116	0,0057	0,0100
Burlington 2519 F 14	-0,0316	0,0014	-0,0049	0,0182	0,0013	0,0136	0,0120	0,0088	0,0076	0,0100
Burlington 2523 M 12	0,0562	0,0090	0,0013	0,0160	0,0087	0,0152	0,0054	-0,0008	-0,0048	-0,0127
Burlington 2523 M 14	0,0370	-0,0045	-0,0158	0,0226	0,0134	0,0108	-0,0042	0,0023	-0,0025	-0,0122
Burlington 2540 F 12	0,0222	-0,0021	-0,0018	-0,0206	-0,0166	0,0142	-0,0092	-0,0022	-0,0017	-0,0051
Burlington 2540 F 14	0,0162	-0,0087	-0,0118	-0,0068	-0,0182	0,0139	-0,0048	-0,0016	0,0013	-0,0093
Burlington 2563 M 12	0,0411	0,0232	0,0007	-0,0045	-0,0046	0,0011	0,0014	0,0058	-0,0035	-0,0126
Burlington 2563 M 14	0,0252	-0,0024	-0,0037	-0,0030	-0,0008	0,0045	0,0087	0,0093	0,0000	-0,0131
Burlington 135 M 12	0,0071	0,0101	0,0066	-0,0012	-0,0014	-0,0007	-0,0184	-0,0026	0,0063	0,0064
Burlington 135 M 14	-0,0051	0,0019	-0,0055	0,0082	0,0029	-0,0044	-0,0191	-0,0015	0,0067	0,0015

Name	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10
Iowa 31 M 12	-0,0162	0,0375	0,0077	-0,0229	0,0125	0,0147	-0,0086	0,0161	-0,0061	-0,0044
Iowa 31 M 14	-0,0160	0,0336	-0,0031	-0,0051	-0,0002	0,0118	-0,0081	0,0222	-0,0093	-0,0043
Oregon 132 F 12	0,0172	0,0036	-0,0080	-0,0237	0,0066	-0,0098	-0,0100	-0,0241	0,0093	-0,0096
Oregon 132 F 14	-0,0036	-0,0082	-0,0166	-0,0170	0,0098	-0,0107	-0,0088	-0,0250	0,0125	-0,0042
Oregon 184 F 12	0,0227	0,0231	0,0142	-0,0084	-0,0055	0,0107	0,0068	-0,0025	-0,0072	0,0119
Oregon 184 F 14	0,0129	0,0176	0,0142	-0,0028	-0,0019	0,0053	0,0044	-0,0080	-0,0129	0,0049
Fels 3994 F 12	0,0126	-0,0129	-0,0059	0,0130	0,0195	-0,0155	-0,0010	0,0037	0,0006	-0,0064
Fels 3994 F 14	0,0082	-0,0187	-0,0094	0,0201	0,0141	-0,0127	-0,0014	0,0094	0,0054	-0,0059
Oregon 240 M 12	0,0451	0,0249	0,0234	-0,0187	0,0009	-0,0001	-0,0181	0,0092	-0,0052	-0,0057
Oregon 240 M 14	0,0371	0,0071	0,0043	-0,0018	0,0010	-0,0076	-0,0238	0,0026	-0,0099	-0,0075
Oregon 316 M 12	-0,0101	0,0261	-0,0074	-0,0005	0,0275	0,0099	0,0028	0,0096	-0,0128	0,0056
Oregon 316 M 14	-0,0391	0,0109	-0,0168	0,0061	0,0281	0,0124	-0,0016	0,0124	-0,0180	0,0053