

# Matching of lateral cephalograms by means of similarity coefficients

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## Abstract:

This was a pilot study to establish the possible applications of taxonomic methods (taxonomy = study of the general principles of classification) to the identification of individuals. Similarity coefficients were calculated from data obtained from standardised orthodontic cephalograms and were used to identify individuals by a process of matching.

There were two test groups and the individuals in the two groups were radiographed on two separate occasions. The first group consisted of young adults who were radiographed twice with approximately six weeks between radiographs. The second group consisted of orthodontic patients who were radiographed prior to and after the completion of orthodontic treatment. The aims were to test the effects of method error, measurement error and growth and treatment changes on the matching potential of similarity coefficients.

The method was found to correctly identify or match all individuals in the first group of young adults, using cephalograms exposed approximately six weeks apart. The differences between the measurements obtained from those cephalograms represented method error and measurement error.

In the second group, where the differences between radiographs further included changes due to growth and treatment, the rate of successful matching was not as high. Despite some limitations the method may be of use in two areas — screening and identification of individuals for forensic purposes and secondly for screening orthodontic cephalograms in diagnosis and treatment planning.

The similarity coefficient chosen was squared Euclidean distance, with variables standardised to zero mean and unit variance to overcome the dimensionality problem caused by different units of measurement.

**Reference:** Aust.Orthod.J. 9(3): 276-281 (1986)

**Key words:** Diagnosis, similarity, forensic, cephalometrics, pattern matching

## INTRODUCTION

*The general process of diagnosis involves the comparison of each new patient's data with the data base acquired by the clinician during study and clinical practice.* Computer aided diagnostic techniques have been shown to be very useful in clinical diagnosis. A variety of strategies has been followed. The present study was directed to a preliminary analysis of the usefulness of similarity coefficients in matching individuals. A number of fields in dentistry might benefit from the application of these methods. The techniques of numerical taxonomy are intuitively appealing and are generally free of assumptions concerning the underlying distributions of the data.

Two fields of application might be appropriate. The first is forensic science where the identification of any person is essentially a matter of matching one set of data derived from post-mortem records with another set of data derived from ante-mortem records. The other field is in the diagnosis and treatment planning of orthodontic patients. While these fields might superficially seem to have little in common, closer examination would suggest that the processes involved in arriving at a 'solution' are much the same, particularly in the evaluation of cephalometric data — at least with the cephalometric analysis techniques currently available.

The forensic identification of individuals has become more complex with increased mobility of the population and the large numbers of individuals involved in some accidents and mass disasters. Despite the sophisticated methods available for determining a deceased person's identity (Salley et al, 1963; Keiser-Nielsen, 1980) in some instances this cannot be established beyond doubt. At these times it may be useful to have supplementary methods to help the examiner.

The identification of individuals by matching ante-mortem and post-mortem radiographs is common (Fatteh and Mann, 1969; Murphy et al, 1980). Dental radiographs

have proven to be of special importance in situations where the remains are severely damaged (Keiser-Nielsen, 1980). Thorne and Thyberg (1953) were among the first to propose the application of lateral skull radiographs in establishing identity. In their original investigation they radiographed 100 subjects twice in a cephalostat, and subsequently they were able to hand match their radiographs on the basis of the individuality of the cranial and facial skeletal features and the dental characteristics.

Later, Sassouni (1959) outlined a systematic procedure for identifying individuals from skull radiographs. His sample consisted of 500 army personnel each of whom had two frontal and two lateral radiographs taken. He evaluated 24 cephalometric measurements and found that the measurements made on frontal radiographs were more useful for identification purposes than measurements made on lateral radiographs. He reduced the number of measurements to eight and tested their usefulness for matching the frontal radiographs of 100 individuals. He was able to match 97 out of 100 radiographs.

Since the introduction of the cephalostat by Broadbent (1931) lateral skull radiographs have been used extensively in *orthodontic diagnosis for the evaluation of the relationships* between the cranial and facial bones, the teeth and the overlying soft tissues. Various cephalometric analyses based on linear and angular measurements have been developed for this purpose (Brown, 1981). Radiographs are taken by standardised techniques and form an important part of an orthodontic patient's pre-treatment records. They are usually stored for a number of years.

The matching of radiographs becomes time consuming and inefficient where large numbers of radiographs must be compared. The purpose of this investigation was to establish if matching methods based on the computation of similarity coefficients from selected

cephalometric measurements would simplify the process. These methods have been applied in various fields for grouping specimens or subjects with similar features (Sokal and Sneath, 1963; Freer, 1972; Hirschfeld and Moyers, 1973). Harmon and Hunt (1977) proposed the use of these methods for identification of facial profiles from photographs.

This study was directed to two questions. Could an individual's radiograph (Time 1) be matched with another radiograph (Time 2) of the same individual, taken about six weeks later? This assumes little or no change in the cranio-facial dimensions of the individual. The differences between the data measured on the two radiographs would arise from variations in positioning the patient in the cephalostat on the two occasions as well as from measurement errors, which Baumrind and Frantz (1971) have shown may be substantial for some variables. Would these differences be large enough to confuse the matching process?

Secondly, could the orthodontic pre-treatment radiographs (Time 1) of an individual be matched with the post-treatment radiographs (Time 2) of the same individual taken 12-24 months later? This assumes considerable change due to growth and orthodontic treatment. Is there a sufficiently stable morphological pattern in the cranio-facial structures, which will not be confounded by the changes due to growth and treatment, to allow the correct matching of individuals after these changes? The assumption is made that each individual has a relatively stable, identifiable underlying cranio-facial pattern.

## MATERIALS AND METHODS

Lateral skull radiographs were obtained for two groups of individuals. The first group comprised 30 dental students at the University of Queensland Dental School who had two lateral skull radiographs taken on separate occasions about six weeks apart. The second group comprised 30 children and young adolescents who had received orthodontic treatment. Patients with skeletal malocclusions were selected, as it was expected that the treatment of these would result in identifiable dento-skeletal changes. The object of selecting these patients was to determine if the effects of growth and treatment would alter the dento-skeletal structures to such an extent that subsequent correct identification was not possible. If correct identification could be made in these cases, it is reasonable to assume that patients undergoing less extensive changes could also be correctly identified. Each individual in this group was represented by one pre-treatment and one post-treatment lateral skull radiograph. The mean time interval between the pre-treatment and post-treatment radiographs was 1.7 years. The mean age of these patients at the start of treatment was 12.3 years and the mean age at the completion of treatment was 14.0 years.

All radiographs were taken under standardised conditions. Each subject was positioned in the cephalostat with the line of sight horizontal and the teeth in centric occlusion. The film-source distance and the distance between the film and the mid-sagittal plane for all individuals were kept constant so that the magnification factor was the same for all radiographs.

Prior to data collection, the radiographic image of each individual was traced twice on cellulose acetate paper and anatomical landmarks transferred to a tracing. These anatomical landmarks were then digitized and the coordinates written to files on a hard disk using a D.E.C. PDP/11 computer\*. Subsequently, angular and linear measurements used for cephalometric analysis were computed from the stored coordinate values (Walker and Kowalski, 1971; Freer, 1980).

The initial choice of any set of variables in a study such as this, is difficult to make. The investigators chose to use the methods of Ricketts (1979) to derive a set of

cephalometric variables which reflect the dento-skeletal structures. It should be pointed out that the authors make no claim that the set of variables used here is necessarily the best set of variables. The choice of an optimum subset of variables is the subject of a separate study.

Theoretically, the most suitable measurements should be those showing the greatest variability between individuals and the highest reproducibility of measurement. Of the twelve variables selected to describe each individual, four were linear (Figure 1) and eight were angular (Figure 2)

## Matching with similarity coefficients

The twelve variable values describing each individual were used to compute similarity coefficients between all individuals. Such coefficients are in the class of proximity measures and form the basis of numerical taxonomy. The aim is to combine like or similar specimens into groups or clusters on the basis of their characteristic features. *By definition, a coefficient of similarity is a measure of similarity between two specimens, computed from a set of their characteristic features.*

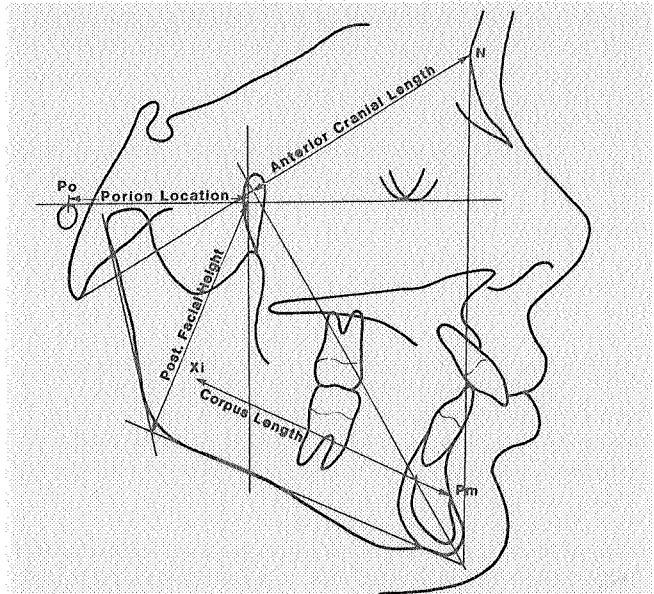


Figure 1: Linear Measurements (After Ricketts)

1. Anterior Cranial Length.
2. Posterior Facial Height.
3. Porion Location.
4. Corpus Length.

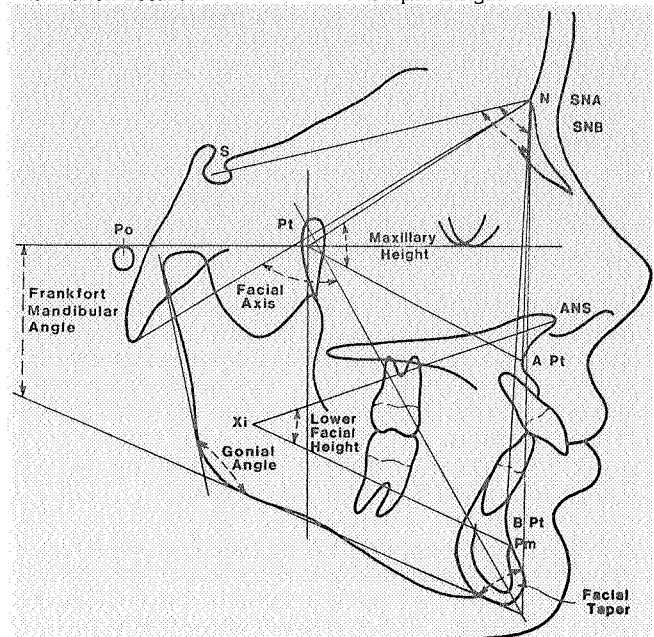


Figure 2: Angular Measurements (After Ricketts)

1. Facial Axis.
2. Frankfort Mandibular Angle.
3. Lower Facial Height.
4. Facial Taper.
5. Maxillary Height.
6. Gonion Angle.
7. Sella-Nasion-A Point Angle.
8. Sella-Nasion-B Point Angle.

Although numerous coefficients have been evolved for various purposes, one of the more widely used similarity coefficients is Euclidean distance. Strictly speaking, such a distance is a measure of dissimilarity as the greater the distance between the individuals, the more dissimilar they are. However, in this study, the more general interpretation of similarity coefficients was used. The coefficient applied here was the squared Euclidean distance which was computed using the following formula:

$$S_{ij} = \frac{[(k(x_{ik} - x_{jk})^2)/n]}{k}$$

where  $x_{ik}$  and  $x_{jk}$  are the values of the measurements of the  $k$ th item made on the radiographs of the  $i$ th and  $j$ th individuals and  $n$  is the total number of measurement items or variables.

A coefficient value was calculated between every individual measured at Time 1 and every individual (including herself/himself) measured at Time 2. In this way, for the first group of dental students, a 30 by 30 matrix of coefficient values was computed and each coefficient value expressed the degree of similarity between the two individuals compared. The more alike any two individuals were, the smaller was the 'distance' computed between them, so that the best match for any individual was the one associated with the lowest coefficient value.

It was hypothesised that the lowest coefficient value would be that value computed from the measurements made on the first and second radiographs of the same individual.

The coefficient is calculated across variables, so that the units of measurement for different variables will affect the size of the coefficient. An effective and acceptable method for overcoming this dimensionality problem is to standardise all variables to zero mean and unit variance.

Ideally, we should recalculate the mean and standard deviation of each variable every time we add measurements from a new radiograph. This recalculation, however, was not performed in the present study and the mean and standard deviation were calculated once only from the base sample, in this case all Time 2 measurements, and these values were used to standardise the variable values for both the base sample and for each new radiograph on which measurements are recorded.

The coefficient calculated between individual 1 at Time 1 and, for example, individual 12 at Time 2, will not be the same as the coefficient calculated between individual 12 at Time 1 and individual 1 at Time 2. This difference reflects differences in variable values due to measurements from the two radiographs. This should not affect the comparative value of the differences between coefficients.

Although the determination of the correct identity of a particular individual is desirable, a reduction in the number of 'possibles' may be valuable. For this reason a shortlist of the five 'best' matches was printed out for each of the 30 dental students. For each individual described by the values measured on the second radiograph, the five most similar individuals described by the values from the first radiograph were determined by means of similarity coefficients. The five individuals were listed in decreasing order of similarity as determined by the increasing values of the coefficients.

The second group was treated in the same way. Each patient described by the post-treatment measurements was matched with every patient described by the pre-treatment measurements and a similarity coefficient was computed for each pair. The five most similar individuals were listed for each of the 30 patients in a rank order based on the values of the coefficients.

## RESULTS

The means, standard deviations and the ranges of the 12 variables measured on the group of 30 dental students are

presented in *Table 1*. The standard deviations and ranges give some indication of the variability of these measurements. *Table 2* summarises the results of the evaluation of the reproducibility of the 12 measurements. Mean differences between the determinations made on the first and second tracings differ significantly from zero ( $P < 0.05$ ) for 3 of the 12 measurements. The percentage of the variance of the differences between the two determinations was expressed as a percentage of the sample variance for each item to further evaluate reproducibility of the selected measurements. *The percentages for the measurements anterior cranial length, porion location, corpus length, maxillary height and sella-nasion-A point indicate some difficulty in locating the landmarks that define these measurements.* As previously explained, they were chosen from a widely recognised cephalometric analysis system.

The results of the matching of the 30 dental students are reproduced in *Table 3*. All of the 30 dental students were correctly identified by the first coefficient. It may be noted that the first coefficient value differs clearly from the second coefficient value in most cases, except for individuals 4 and 10. This indicates that individuals 7 and 30 respectively, listed as second choices for individuals 4 and 10 were also similar to individuals 4 and 10 in terms of the 12 selected measurements. The difference between coefficients 4-4 and 4-7 was only 0.1 while the difference between coefficients 10-10 and 10-30 was 0.29. There is no statistical test against which to measure these differences. Simply, one aims to get the biggest possible difference between the coefficients for the first and second matches.

*Table 4* shows the results of the matching for the 30 orthodontically treated patients. In this group, correct first matches occurred for 21 (70%) individuals. In addition, 28 individuals were identified in the first five

*Table 1.* Sample statistics for the 12 craniofacial measurements made on the first radiograph of the 30 dental students

| Measurement                | Mean  | SDT | Range |
|----------------------------|-------|-----|-------|
| Anterior cranial length    | 66.0  | 4.3 | 16.4  |
| Posterior facial height    | 72.1  | 5.7 | 23.0  |
| Porion location            | 41.9  | 3.1 | 12.3  |
| Corpus length              | 77.6  | 3.5 | 15.5  |
| Facial axis                | 91.2  | 3.9 | 17.1  |
| Frankfort mandibular angle | 21.4  | 5.7 | 24.3  |
| Lower facial height        | 43.1  | 4.4 | 21.0  |
| Facial taper               | 67.4  | 5.1 | 22.6  |
| Maxillary height           | 55.6  | 3.3 | 12.6  |
| Gonial angle               | 124.8 | 6.3 | 23.8  |
| Sella nasion A point angle | 82.0  | 3.9 | 16.3  |
| Sella nasion B point angle | 79.9  | 3.7 | 20.6  |

*Table 2.* Statistical analysis (paired t-test) of the differences between the first and second determinations of the 12 cranio-facial measurements made on the first radiographs of the 30 dental students.

| Measurement                                | Mean  | SDd  | difference |
|--------------------------------------------|-------|------|------------|
| (SDd <sup>2</sup> /SDT <sup>2</sup> × 100) |       |      |            |
| Anterior cranial length                    | 0.36  | 1.63 | 14.4       |
| Posterior facial height-0.33               | 1.34  | 5.5  |            |
| Porion location                            | 0.55* | 1.14 | 13.5       |
| Corpus length                              | 0.16  | 1.35 | 14.8       |
| Facial axis                                | 0.69* | 1.33 | 11.6       |
| Frankfort mandibular angle                 | 0.44  | 1.77 | 9.6        |
| Lower facial height                        | 0.62* | 1.28 | 8.5        |
| Facial taper                               | -0.10 | 0.85 | 2.8        |
| Maxillary height                           | -0.33 | 1.34 | 16.4       |
| Gonial angle                               | 0.06  | 1.60 | 6.5        |
| Sella nasion A point angle                 | 0.25  | 1.51 | 15.0       |
| Sella nasion B point angle                 | -0.07 | 1.15 | 9.6        |

\*Significant .05 level

SDd Standard deviation of differences

SDT Sample standard deviation of measurements

coefficients. In most instances where the individuals were correctly identified by the first coefficient, there was a comparatively large difference between the first and second coefficient values, which assured good discrimination. A comparison of the first coefficient values in *Tables 3* and *4* reveals that those in *Table 4* are generally larger. This increase in coefficient values or 'distance' was probably the result of changes due to growth and treatment.

## DISCUSSION

The matching of records is often time consuming. The method investigated in this study would provide a simple

and objective approach to identification, and might prove most useful as a preliminary sieving device where cephalograms are available. There would seem to be two fields of possible application - in forensic dentistry and in orthodontic diagnosis and treatment planning. The general principles of record matching in forensic dentistry are well understood. What is not so commonly understood is that the utilisation of cephalometric data in orthodontic diagnosis is also basically a process of matching.

All of the current methods of cephalometric analysis with which the authors are familiar, depend finally upon a comparison with some classification of types. Any classification requires a condensation of information *in*

**Table 3.** Results of matching 30 dental students. For each student described by the values measured on the second radiograph, the five most similar students described by the values measured on the first radiograph are listed with the coefficients underneath. All are correctly identified by the first coefficient.

| Student |      |      |      |      |      | Student |      |      |      |      |      | Student |      |      |      |      |      |
|---------|------|------|------|------|------|---------|------|------|------|------|------|---------|------|------|------|------|------|
| No.     | 1    | 2    | 3    | 4    | 5    | No.     | 1    | 2    | 3    | 4    | 5    | No.     | 1    | 2    | 3    | 4    | 5    |
| 1       | 1    | 12   | 22   | 19   | 13   | 11      | 11   | 22   | 28   | 7    | 13   | 21      | 21   | 29   | 25   | 15   | 20   |
|         | 1.17 | 2.20 | 2.77 | 2.92 | 3.10 |         | 0.95 | 4.44 | 4.56 | 4.69 | 4.94 |         | 1.13 | 3.37 | 3.86 | 4.53 | 4.96 |
| 2       | 2    | 16   | 17   | 13   | 9    | 12      | 12   | 1    | 19   | 22   | 20   | 22      | 22   | 1    | 4    | 7    | 12   |
|         | 1.51 | 4.24 | 4.63 | 4.84 | 4.90 |         | 1.24 | 1.97 | 2.49 | 3.58 | 3.68 |         | 1.73 | 2.49 | 3.21 | 3.27 | 3.93 |
| 3       | 3    | 9    | 8    | 2    | 6    | 13      | 13   | 16   | 1    | 19   | 22   | 23      | 23   | 5    | 10   | 25   | 30   |
|         | 0.78 | 2.92 | 4.09 | 4.29 | 4.70 |         | 0.86 | 3.76 | 3.79 | 3.98 | 4.22 |         | 1.01 | 3.70 | 3.95 | 4.30 | 4.48 |
| 4       | 4    | 7    | 28   | 22   | 30   | 14      | 14   | 12   | 19   | 6    | 1    | 24      | 24   | 30   | 10   | 7    | 27   |
|         | 1.69 | 1.79 | 2.71 | 3.25 | 3.25 |         | 1.29 | 4.32 | 4.42 | 4.94 | 4.98 |         | 0.83 | 4.23 | 5.05 | 5.18 | 5.24 |
| 5       | 5    | 25   | 10   | 18   | 7    | 15      | 15   | 30   | 25   | 29   | 18   | 25      | 25   | 20   | 5    | 28   | 15   |
|         | 1.05 | 2.61 | 3.26 | 3.31 | 3.43 |         | 0.79 | 3.04 | 3.63 | 3.65 | 3.68 |         | 0.84 | 2.59 | 2.90 | 3.15 | 3.22 |
| 6       | 6    | 3    | 17   | 2    | 8    | 16      | 16   | 9    | 2    | 3    | 15   | 26      | 26   | 8    | 20   | 12   | 13   |
|         | 1.25 | 4.20 | 4.41 | 4.46 | 4.85 |         | 1.52 | 2.83 | 3.21 | 4.18 | 4.31 |         | 1.77 | 2.98 | 3.22 | 3.31 | 4.02 |
| 7       | 7    | 4    | 28   | 22   | 30   | 17      | 17   | 13   | 1    | 12   | 6    | 27      | 27   | 24   | 30   | 23   | 10   |
|         | 1.71 | 2.42 | 2.51 | 2.87 | 3.61 |         | 0.80 | 3.87 | 4.10 | 4.22 | 4.30 |         | 0.68 | 4.47 | 5.19 | 5.34 | 5.54 |
| 8       | 8    | 26   | 28   | 30   | 15   | 18      | 18   | 15   | 30   | 5    | 28   | 28      | 28   | 22   | 20   | 7    | 25   |
|         | 1.07 | 2.82 | 3.53 | 3.99 | 4.01 |         | 1.03 | 3.57 | 3.66 | 3.80 | 4.22 |         | 1.29 | 2.79 | 2.86 | 3.04 | 3.07 |
| 9       | 9    | 3    | 16   | 2    | 15   | 19      | 19   | 12   | 1    | 20   | 13   | 29      | 29   | 15   | 25   | 21   | 23   |
|         | 1.32 | 2.77 | 3.01 | 3.58 | 4.29 |         | 0.68 | 3.10 | 3.14 | 3.92 | 3.94 |         | 0.94 | 3.19 | 3.31 | 3.61 | 4.18 |
| 10      | 10   | 30   | 28   | 15   | 23   | 20      | 20   | 25   | 19   | 12   | 5    | 30      | 30   | 15   | 10   | 18   | 28   |
|         | 2.58 | 2.87 | 3.42 | 3.74 | 3.84 |         | 1.65 | 2.76 | 3.59 | 4.14 | 4.43 |         | 0.75 | 3.26 | 3.35 | 3.41 | 3.47 |

**Table 4.** Results of matching 30 orthodontic patients. For each patient described by the post-treatment values, the five most similar patients described by the pre-treatment values are listed with the coefficient underneath.

| Patient |      |      |      |      |      | Patient |      |      |      |      |      | Patient |      |      |      |      |      |
|---------|------|------|------|------|------|---------|------|------|------|------|------|---------|------|------|------|------|------|
| No.     | 1    | 2    | 3    | 4    | 5    | No.     | 1    | 2    | 3    | 4    | 5    | No.     | 1    | 2    | 3    | 4    | 5    |
| 1       | 1    | 7    | 28   | 20   | 13   | 11*     | 5    | 11   | 24   | 23   | 15   | 21      | 21   | 17   | 23   | 13   | 28   |
|         | 1.74 | 2.24 | 2.62 | 3.24 | 3.31 |         | 2.85 | 3.38 | 4.07 | 4.12 | 4.30 |         | 1.80 | 3.14 | 3.98 | 4.03 | 4.04 |
| 2       | 2    | 19   | 23   | 24   | 10   | 12      | 12   | 27   | 10   | 30   | 4    | 22*     | 10   | 22   | 12   | 30   | 27   |
|         | 2.43 | 2.48 | 3.64 | 3.97 | 4.15 |         | 3.12 | 4.11 | 4.31 | 4.83 | 4.95 |         | 2.08 | 3.11 | 3.25 | 3.42 | 3.90 |
| 3†      | 5    | 11   | 13   | 10   | 20   | 13*     | 23   | 17   | 13   | 2    | 28   | 23      | 23   | 24   | 2    | 5    | 17   |
|         | 2.63 | 3.12 | 3.31 | 3.36 | 3.48 |         | 2.29 | 2.39 | 2.91 | 3.15 | 3.26 |         | 2.28 | 3.70 | 3.95 | 4.37 | 4.38 |
| 4       | 4    | 10   | 17   | 19   | 27   | 14      | 14   | 10   | 26   | 20   | 13   | 24*     | 19   | 24   | 23   | 2    | 5    |
|         | 1.16 | 4.57 | 5.13 | 5.19 | 5.28 |         | 2.24 | 3.09 | 3.31 | 3.66 | 4.06 |         | 3.46 | 3.49 | 3.99 | 4.10 | 4.61 |
| 5       | 5    | 23   | 11   | 2    | 14   | 15      | 15   | 15   | 8    | 7    | 5    | 25*     | 15   | 25   | 7    | 8    | 5    |
|         | 2.71 | 4.00 | 4.39 | 4.59 | 4.82 |         | 1.24 | 2.89 | 4.60 | 4.93 | 5.14 |         | 2.06 | 2.19 | 5.29 | 5.30 | 5.80 |
| 6       | 6    | 3    | 29   | 28   | 13   | 16      | 16   | 21   | 28   | 13   | 20   | 26      | 26   | 14   | 27   | 12   | 10   |
|         | 1.90 | 3.43 | 4.41 | 4.42 | 4.46 |         | 2.76 | 3.29 | 3.29 | 3.60 | 3.76 |         | 2.45 | 3.34 | 3.83 | 3.88 | 4.15 |
| 7       | 7    | 23   | 24   | 5    | 15   | 17      | 17   | 4    | 21   | 23   | 13   | 27      | 27   | 12   | 10   | 30   | 44   |
|         | 1.68 | 2.97 | 3.30 | 3.31 | 3.32 |         | 3.23 | 3.61 | 4.29 | 4.63 | 4.80 |         | 1.82 | 4.18 | 4.99 | 5.14 | 5.21 |
| 8       | 8    | 15   | 7    | 23   | 24   | 18      | 18   | 24   | 8    | 2    | 19   | 28*     | 23   | 28   | 24   | 17   | 21   |
|         | 2.22 | 3.60 | 3.73 | 3.86 | 4.04 |         | 3.57 | 4.96 | 5.33 | 5.52 | 5.53 |         | 2.11 | 2.85 | 3.25 | 3.38 | 3.39 |
| 9       | 9    | 28   | 5    | 23   | 13   | 19      | 19   | 2    | 10   | 30   | 24   | 29*     | 11   | 29   | 5    | 1    | 2    |
|         | 2.39 | 3.23 | 3.36 | 3.49 | 3.54 |         | 1.30 | 4.04 | 4.14 | 4.73 | 4.79 |         | 2.55 | 2.96 | 3.63 | 3.88 | 4.32 |
| 10      | 10   | 30   | 19   | 2    | 27   | 20*     | 13   | 28   | 20   | 17   | 23   | 30      | 30   | 19   | 2    | 10   | 23   |
|         | 2.05 | 3.09 | 3.65 | 3.98 | 4.02 |         | 1.43 | 1.62 | 1.64 | 2.25 | 2.62 |         | 2.14 | 3.20 | 3.22 | 3.31 | 4.46 |

\* individual not identified correctly by the first coefficient

† individual not identified among the first five coefficients

*order to reduce the classificatory groups to a manageable number.* This process of condensation results in the loss of some information, in the classical sense. *The method outlined in this investigation has the potential to widen the classificatory base to as many groups as the investigator wishes.* If the comparison sample contains a thousand cases, the incoming or new individual may be matched with any one of the thousand.

The coefficients are computed from measurements made on skull radiographs. These measurements incorporate errors inherent in the radiographic method and errors due to landmark identification (Baumrind and Frantz, 1971; Thurrow, 1977; Bergensen, 1980). The radiographs are two-dimensional projections of a three dimensional structure. The images are always enlarged and the enlargement of structures in different planes results in distortion. Although the method for taking profile skull radiographs is standardised, different machines use different focus-film distances resulting in different enlargement factors. Precise repositioning of individuals in any head holder is difficult, and this results in slightly different images each time. While it is not possible to simulate the conditions which might prevail in the circumstances of a mass disaster, the methods used did address the effects of measurement error and changes due to growth and treatment on matching procedures. If the method is robust enough to remain useful in cases undergoing orthodontic treatment, it might be expected that x-rays taken 5 or 10 years previously would still contain valuable information.

The radiographs on which this study was based were taken under essentially the same conditions, so that the enlargement remained constant. The varying rates of magnification with different cephalostats would clearly be a problem to be addressed if the radiographs from these different machines were to be compared. There are a number of simple solutions including the use of angular and ratio variables rather than direct measurements. It seems most unlikely that correction for magnification could be undertaken in many cases because the magnification rate would not be known.

For useful forensic discrimination between individuals, it is important that the coefficient value, computed between ante-mortem and post-mortem data of the same individual, express the highest degree of similarity. In taxonomic terms the 'distance' computed between the ante-mortem and post-mortem data of a particular individual should be small and should differ by as large a margin as possible from the 'distances' computed between that and any other individual.

In the second experimental group, the discriminative potential of the coefficients was affected by growth and treatment changes. Rohlf (1970) pointed out that *as the number of measurements used in the computation of the coefficient increases, the discrimination becomes more robust.* However, as more measurements are introduced the more complex and time consuming the process becomes, especially when many individuals have to be compared. It is preferable to use measurements that describe stable structures which are known not to change significantly with growth and treatment.

The method was very effective for identifying adult individuals whose cranio-facial features were not changed by growth or treatment, and it might be particularly useful for identification of edentulous individuals, if cranio-facial rather than dento-alveolar features were used. It could be a valuable screening device for reducing the number of possibles for individuals involved in mass disasters. This would considerably reduce the time spent in finding the likely matches for the unknown individuals. The process could be simplified further by eliminating the tracing stage, and scanning the radiographic images directly into a computer, as proposed by Harmon et al (1978).

From the orthodontic viewpoint, the possibilities are quite interesting. Currently, some clinicians 'predict' future growth vectors for the individual by comparing that individual's morphology pattern with morphological patterns deemed to be important by the cephalometric analysis. For example, in the Ricketts system if the individual's morphology is brachyfacial, certain assumptions and conclusions follow and from these, along with other information, the treatment plan is formulated.

These methods rely heavily on the assumption that because person A has a particular morphology and grew in a known direction and, furthermore, because person B has the same morphology, and is equivalent in other ways, person B will grow in basically the same way as person A. This method is known to be passably accurate although it does not prove or disprove the growth-morphology assumption. *It may be that the assumption is wrong although the predictive value of the method is clinically useful.* From a practical viewpoint, it is necessary to use the present method or other matching processes to specifically test the growth-morphology assumption.

## SUMMARY

This preliminary investigation sought to test the usefulness of similarity coefficients for matching the records of the same person taken on two separate occasions. There were two test groups. The first group comprised young adults for whom two lateral cephalograms were taken approximately six weeks apart. The differences between the variable values measured on these cephalograms were due to method and measurement errors. For this group, the method was successful in all cases. The second group comprised orthodontic patients who had cephalograms taken before and after treatment. The differences between the variable values measured on these two cephalograms were due to errors and changes resulting from growth and treatment. The matching process was not as successful in this group but was still encouraging enough to suggest that the method might be explored further for possible applications in forensic dentistry and in the classification and analysis of lateral cephalograms prior to orthodontic treatment.

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