Precision of measurements on conventional negative ‘bones white’ and inverted greyscale ‘bones black’ digital lateral cephalograms

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SUMMARY The objective of this study was to determine whether the accuracy of measurement data from inverted greyscale digital cephalometric radiographs equals that obtained from conventional negative digital cephalometric radiographs. Fifty-five consecutively lateral cephalometric radiographs from a university orthodontic clinic obtained for treatment planning were used for this study. A 5 MB conventional negative ‘bones white’ and inverted greyscale ‘bones black’ TIFF digital image of each radiograph was produced. These were allocated a unique identifier and were analysed in random order by one clinician. Eighteen cephalometric landmarks were digitized using the Opal 2.1 package and the angles were calculated. The angular measurements were compared using two-sample $t$-tests ($P < 0.05$).

The angular measurements from the conventional negative bones white and inverted greyscale bones black lateral cephalometric radiographs were neither statistically significantly different nor clinically different from each other. Therefore, measurements derived from conventional negative bones white and inverted greyscale bones black lateral cephalometric radiographs have a similar level of precision.

Introduction

Cephalometric radiography is a standardized and reproducible form of skull radiography to assess the relationships of the teeth to the jaws and the jaws to the rest of the facial skeleton (Whaites, 2002). In routine clinical practice, lateral cephalometric radiographs are recorded during orthodontic treatment to assess malocclusions and aid both non-surgical and surgical treatment planning, as well as monitoring the progress of treatment. In addition, there are many other indications for the recording of lateral cephalometric radiographs including the localisation of unerupted teeth and in planning the locations of dental implants in edentulous subjects.

There are many potential sources of error in cephalometrics including radiographic technique, patient positioning, landmark identification, and measurements. These have been widely investigated (Baumrind and Frantz, 1971a,b; Gravely and Benzies, 1974; Cohen, 1984; Houston et al., 1986; Battagel, 1993; Turner and Weerakone, 1993; Chen et al., 2000, 2004) with landmark identification being determined to be the main source of error in the measurement of the craniofacial complex when using cephalometry (Richardson, 1966; Baumrind and Frantz, 1971a,b; Gravely and Benzies, 1974). The difficulty in identifying cephalometric landmarks is mainly due to the superimposition of the right and left paired anatomical structures resulting from craniofacial asymmetries and positioning errors within the cephalostat. This leads to landmarks appearing as double or blurred images on lateral cephalograms (Richardson, 1966; Baumrind and Frantz, 1971a,b; Gravely and Benzies, 1974; Silveira and Silveira, 2006) and by convention, the midpoint of the two is recorded. Furthermore, the error of the method should be minimal otherwise it is doubtful whether any differences between images are attributable to growth and treatment effects, among other variables (Kamoen et al., 2001).

The use of ‘on-screen’ facilities for landmark identification was first used by Jackson et al. (1985) who found the errors associated with their digital image system comparable with those from conventional cephalometry. Subsequently, studies investigating landmark and measurement reproducibility using direct digital cephalograms have not been conclusive. Chen et al. (2000) found landmark reproducibility to be inferior, whereas Lim and Foong (1997) found digital cephalometry to be associated with an indifferent level of landmark reproducibility in comparison with that associated with conventional cephalometry. In contrast, Hagemann et al. (2000) found direct digital cephalograms to be associated with greater landmark reproducibility than conventional cephalograms. In a more recent study, it was noted that the errors associated with cephalometric measurements were comparable when derived from either analogue films or from those scanned at 300 dots per inch (Ongkosuwito et al., 2002). With direct digital cephalograms captured and stored using a picture archiving and communication system, image
quality can be altered by enhancing the contrast and therefore
discrete anatomical edges may be more easily delineated.

One method of altering the image format is to invert the
greyscale properties to ‘bones black’ in comparison with
the conventionally accepted ‘bones white’ cephalograms
(Figure 1). Although Haak and Wicht (2005) found that
this procedure did not enhance the detection of approximal
caries and Kheddache et al. (1991) did not find any
significant difference in the detectability of the test
structures when comparing positive (bones black) and
negative (bones white) chest radiographs using a true
greyscale reversal. No evidence is available to determine if
inverted greyscale lateral cephalograms are associated
with a different level of landmark reproducibility than
conventional bones white cephalograms.

The aim of the present study was to determine whether the
precision of measurement data associated with inverted
greyscale digital cephalometric radiographs is different to that
associated with conventional negative bones white digital
cephalometric radiographs. The null hypothesis tested was that
there are no statistically significant differences in the precision
of cephalometric measurements between conventional
negative and inverted greyscale lateral cephalograms.

Materials and Methods
Caldicott Guardian approval was obtained for the use of 55
consecutive lateral cephalometric radiographs recorded
from 1 January 2006 at a university orthodontic clinic to
investigate the precision of cephalometric measurements
using different cephalometric image formats. Caldicott
Guardian approval was necessary as the images were
patient-identifiable and the patients had not given consent
for use of their radiographs in research when they were
recorded for clinical purposes. The original cephalometric
images were identified from the Sidexis radiography server
(www.sidexis.com). The patients when all at the
commencement of orthodontic treatment where the lateral
cephalometric radiographs had been recorded for diagnostic
and treatment planning purposes. As a result, medical
ethics committee approval was not required. Images were
only selected with optimal cephalogram quality to facilitate
landmark identification, where all incisor teeth were fully
erupted and where the soft tissue nasal tip and chin were
visible on the image. The sample size was calculated using
a clinically significant difference in angular measurements
of 2 degrees as determined by McIntyre and Mossey (2002)
at 80 per cent power. The cephalometric radiographs were
acquired using an OrthoPlus DS digital cephalometer
(Siemens, Munich, Germany), where the subjects were
positioned with the Frankfort plane parallel to the floor.

A 5 MB conventional negative bones white (Figure 1a)
and inverted greyscale bones black (Figure 1b) TIFF digital
image of each radiograph was produced. These were
anonimized and allocated a unique identifier by one author

![Figure 1](https://academic.oup.com/ejo/article-abstract/34/1/57/516198)
angles (Table 2). The Opal data were exported into an Excel spreadsheet (Microsoft Inc, Redmond, California, USA) and the values rounded up or down to the nearest 0.1 degree in relation to the pixel pitch value of the monitor.

Statistical analysis

The angular measurements for each parameter were compared using two-sample t-tests to determine statistical significance. In order to evaluate individual landmark intra-operator repeatability, 25 of the images were re-measured 1 month later (Houston, 1983). Random and systematic errors were calculated using the formula of Dahlberg (1940) and a two-sample t-test (Houston, 1983), respectively. The level of significance was set at $P < 0.05$ for the systematic error.

Results

The random error did not exceed 0.5 degrees and the systematic errors did not exceed the level of significance set at $P < 0.05$. The angular measurements for the inverted greyscale bones black lateral cephalometric radiographs were neither statistically nor clinically significantly different to those of the conventional negative bones white lateral cephalometric radiographs ($P > 0.05$). However, the variability of seven of the parameters (SNA, SNB, MMPA, angle between the maxillary incisor and maxillary plane, inter-incisal angle, nasolabial angle, and Holdaway angle) were lower in the inverted greyscale bones black images in contrast to the conventional negative bones white images (Table 3).

Discussion

In this study, it was found that measurements using inverted greyscale bones black lateral cephalometric radiographs were neither statistically nor clinically significantly different to those from conventional negative bones white lateral cephalometric radiographs. The null hypothesis was therefore supported. However, it was interesting to note that the variability of the measurements was lower for seven of the 10 parameters in the inverted greyscale bones black group. As the greyshade bones black lateral cephalometric radiographs were neither statistically nor clinically significantly different to those of the conventional negative bones white lateral cephalometric radiographs ($P > 0.05$). However, the variability of seven of the parameters (SNA, SNB, MMPA, angle between the maxillary incisor and maxillary plane, inter-incisal angle, nasolabial angle, and Holdaway angle) were lower in the inverted greyscale bones black images in contrast to the conventional negative bones white images (Table 3).

Table 1  Cephalometric landmarks.

<table>
<thead>
<tr>
<th>Landmark</th>
<th>Description</th>
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<tbody>
<tr>
<td>Sella</td>
<td>Central point by eye estimation of the pituitary fossa</td>
</tr>
<tr>
<td>Nasion</td>
<td>Most anterior point of the fronto-nasal suture</td>
</tr>
<tr>
<td>Upper incisor apex</td>
<td>Root apex of the most anterior maxillary central incisor</td>
</tr>
<tr>
<td>Upper incisor tip</td>
<td>Incisal edge of the most prominent maxillary central incisor</td>
</tr>
<tr>
<td>Lower incisor tip</td>
<td>Incisal edge of the most prominent mandibular central incisor</td>
</tr>
<tr>
<td>Lower incisor apex</td>
<td>Root apex of the most anterior mandibular central incisor</td>
</tr>
<tr>
<td>Point B</td>
<td>The point on the anterior surface of the mandibular symphysis between infradentale and pogonion which is furthest from a line joining these points</td>
</tr>
<tr>
<td>Point A</td>
<td>The point on the anterior surface of the maxillary which is furthest from a line joining anterior nasal spine and prosthion</td>
</tr>
<tr>
<td>Pogonion</td>
<td>Most anterior point of the bony chin in the median plane</td>
</tr>
<tr>
<td>Menton</td>
<td>Most inferior point on the mandibular symphysis</td>
</tr>
<tr>
<td>Gonion</td>
<td>Constructed point at the intersection of the posterior and lower borders of the mandible</td>
</tr>
<tr>
<td>Anterior nasal spine</td>
<td>Tip of the anterior bony spine of the maxilla</td>
</tr>
<tr>
<td>Posterior nasal spine</td>
<td>Most posterior point on the outline of the hard palate</td>
</tr>
<tr>
<td>Soft tissue nasion</td>
<td>Point of deepest concavity of the soft tissue contour of the root of the nose</td>
</tr>
<tr>
<td>Columella</td>
<td>Point at the junction of the nasal base and the superior labial sulcus</td>
</tr>
<tr>
<td>Labrale superius</td>
<td>Median point in the upper margin of the upper membranous lip</td>
</tr>
<tr>
<td>Labrale inferior</td>
<td>Median point in the lower margin of the lower membranous lip</td>
</tr>
<tr>
<td>Soft tissue pogonion</td>
<td>Most prominent point on the soft tissue contour of the chin</td>
</tr>
</tbody>
</table>

Table 2  Cephalometric measurements.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>SNA</td>
<td>Angle between sella–nasion and nasion–point A</td>
</tr>
<tr>
<td>SNB</td>
<td>Angle between sella–nasion and nasion–point B</td>
</tr>
<tr>
<td>ANB</td>
<td>SNA minus SNB</td>
</tr>
<tr>
<td>S-N/maxillary plane angle</td>
<td>Angle between sella–nasion and the maxillary plane (ANS-PNS)</td>
</tr>
<tr>
<td>MMPA</td>
<td>Angle between the maxillary plane (ANS-PNS) and the mandibular plane (gonion–menton)</td>
</tr>
<tr>
<td>Maxillary incisor/maxillary plane</td>
<td>Posterio-inferior angle between the upper incisor long axis and the maxillary plane</td>
</tr>
<tr>
<td>Mandibular incisor/mandibular plane</td>
<td>Posterio-superior angle between the mandibular plane and the long axis of the lower incisor</td>
</tr>
<tr>
<td>Inter-incisal angle</td>
<td>Angle formed by the intersection of the long axes of the upper and lower incisors</td>
</tr>
<tr>
<td>Nasolabial angle</td>
<td>Angle between columella–subnasale and subnasale–labrale superius</td>
</tr>
<tr>
<td>Holdaway angle</td>
<td>Angle between soft tissue nasion/soft tissue pogonion/labrale superius</td>
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radiographs originated from the same patient cohort, there would be no bias resulting from subject selection and therefore the reduced variability in the inverted-grey scale bones black group indicates that cephalometric measurements using this image format are likely to be marginally more precise.

It is interesting that despite many digital radiography packages having the facility to produce inverted greyscale images, the clinical utility of this image format has not been investigated. However, it is reassuring to note that the finding of no statistically or clinically significant differences between the measurements made on inverted greyscale bones black and conventional negative bones white lateral cephalometric radiographs is in line with the results of Haak and Wicht (2005) and Kheddache et al. (1991) who found there to be no improvement in the detection of approximal caries and detectability of their test structures using chest radiographs, respectively.

Nevertheless, the reduced variability in the measurement data for the inverted greyscale bones black lateral cephalometric radiograph group could indicate that certain landmarks are more reproducible when using this image format. This may be due to the improvement in contrast that occurs when inverting the greyscale or perhaps rendering the anatomical structures as ‘positive’ which may be easier to identify by the human eye.

Cephalometric imaging formats have been investigated widely and it has been noted that only minor differences exist in the reproducibility of landmarks and measurement data when comparing analogue film, monitor-displayed digital images, and laser printer images of cephalograms (Geelen et al., 1998). It would be interesting to determine if laser printer images of inverted greyscale cephalometric radiographs were also associated with a similar level of precision in relation to the eventual measurement data that is produced in cephalometric analysis.

All studies are associated with bias that can influence the results. In this study, bias may have contributed to the results from the original cohort of subjects and the cephalometric analysis that was selected. Although the cohort of subjects were a consecutive series of referred patients, because they were referred to a university orthodontic clinic, it is likely that they represented the extremes of malocclusion and therefore were relatively heterogeneous. This explains the level of variability in the measurements which was higher than desirable. The cephalometric analysis selected comprised exclusively angles and no linear distance measurements or ratios were included because linear distance measurements are influenced by magnification of individual cephalograms (McIntyre and Mossey, 2003). Nevertheless, it is unlikely that including these would have any effect on the final results of this study.

### Conclusion

Measurements made using conventional negative bones white and inverted greyscale bones black lateral cephalometric radiographs have a similar level of precision.

### References


Richardson A 1966 An investigation into the reproducibility of some points, planes and lines used in cephalometric analysis. American Journal of Orthodontics 52: 637–651

