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Calibration Factor for Conventional Linear Cephalometric Measurements

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الخلاصة

الاهداف: من هذه الدراسة هو تحديد قيمة عامل المعايرة للقضاء على التشويه في قياسات الرأس الخطية. **المواد وطرائق العمل**: أجريت الدراسة على ٥جماجم جافة ، الجمجمة الأولى تحتوي على ١٢ علامة ظلية للأشعة مثبتة في مستويات مختلفة، ثم صورت شعاعيا بواسطة الأشعة السينية لقياسات الرأس الرقمية. تم قياس المحورين الافقي والعامودي (X و Y) لكل علامة ظلية للأشعة المستخدمة في تقدير عامل المعايرة. كما تم قياس ثماني مسافات خطية بصورة مباشرة و بالأشعة السينية التقليدية للجماجم الخمسة لتقييم عامل المعايرة المحدد في الدراسة. **النتائج**: أظهرت النتائج فرقا غير معنوي ($P > 0.05$) بين القياسات الشعاعية المباشرة والمعايرة على اشعة الراس الرقمية والتقليدية. بينما وجد اختلاف كبير بين القياسات الخطية لقياسات الرأس التقليدية بالمقارنة مع القياسات التشريحية المباشرة والقياسات الخطية لأشعة الرأس التقليدية مع تلك القياسات المعاملة بواسطة عامل المعايرة ($P < 0.05$). **الاستنتاجات**: وجدت هذه الدراسة أن القياسات الخطية لقياسات الرأس التقليدية يمكن أن تكون أكثر موثوقية كما في القياسات الخطية الرقمية لأشعة الرأس، إذا تم معايرتها من قبل عامل المعايرة (١.٠٨) الذي تحدده الدراسة.

ABSTRACT

Aims: the aim of this study is to determine a calibration factor to eliminate the distortion in the linear cephalometric measurements. **Materials and Methods**; the study was performed on the 5 dry skulls, the first skull contained 12 radiopaque markers fixed at different plains, and radiographed by digital cephalometric x-ray machine. The X and Y axes of the shadow of each radiopaque marker used to estimate the calibration factor. Eight linear distances measured directly and radiographically on the conventional cephalographs of the 5 skulls to evaluate the detected calibration factor. **Results**; the results showed no-significant difference ($p > 0.05$) between the direct and calibrated radiographic measurement on the digital and conventional cephalographs. whereas significant difference was found between the conventional cephalometric linear measurements as compared with direct anatomical linear and the conventional cephalometric linear measurements with those measurements manipulated with the estimated calibration factor ($p < 0.05$). **Conclusions**; this study found that the conventional cephalometric linear measurements could be reliable as that of digital cephalometric linear measurements, if it's calibrated by the calibration factor (1.08) which is estimated by the present study.

Key words: calibration factor, digital radiograph, conventional cephalometric radiograph, linear measurements

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INTRODUCTION

Conventional cephalometric analysis, is a treatment tool as a part of the orthodontic records, it includes lateral cephalograms and represented by widely used linear and angular measurements[1,2,3]. Digital cephalometry is a better tool in clinical orthodontics, the cephalometric analysis, must be as comparable and reliable as it is on conventional radiographic film, which is still considered as the golden standard in contemporary orthodontics[4,5,6]. However, still there is variation with lateral cephalograms lead to change in the magnification and distortion especially with linear measurements[7,8]. Image size distortion (magnification) is the increase in size of the image on radiograph compared with actual size of the object. The divergent paths of photons in an x-ray beam that cause an enlargement of the image on a radiograph[9,10]. The image distortion may be different at different parts of the x-ray beam pathway. Thus, two or more objects may have different distortions when positioned at the locations with different distances from the image receptor[3,11]. The aim of this study is to determine a calibration factor used to eliminate the distortion from the linear cephalometric measurements.

MATERIAL AND METHODS

The study performed on the five dry skulls, the first skull contained 12 radiopaque markers (stainless steel balls with 3.95 mm diameter) fixed with soft wax to be at a different sagittal plains from the image receptor[12,13] (Table - 1).

Table (1): list of radiopaque marker sites.

No.	Site of Markers
1	The deepest point of the nasal bridge.
2	The center of the Sella turcica.
3	Anterior nasal spine.
4	Posterior nasal spine.
5	Midline of the mandibular symphysis.
6	Mental foramen (left side).
7	Crest of the alveolar ridge in lower premolar region (Left side).
8	Crest of the alveolar ridge in lower 2nd molar region (Right side).
9	The external surface of the ramus opposing to the mandibular foramen (right side).
10	The external surface of the ramus opposing to the mandibular foramen (left side).
11	Crest of the alveolar ridge in upper premolar region (right side)*.
12	Crest of the alveolar ridge in upper premolar region (left side)*.

* excluded value.

The skull fixed and masked with elastic transparent bandage on the cephalostate of Planmeca Dimaxis Pro x-ray machine - Finland (Figure -1; A), which operated at 8 mA, 78 kVp, and 23 sec. scanning time. The digital cephalometric images stored in the data base as TIFF format (tagged image file format). The X and Y axes of the shadow of each radiopaque marker (stainless steel balls) were measured twice by Dimaxis classic imaging software (Figure -1; B).

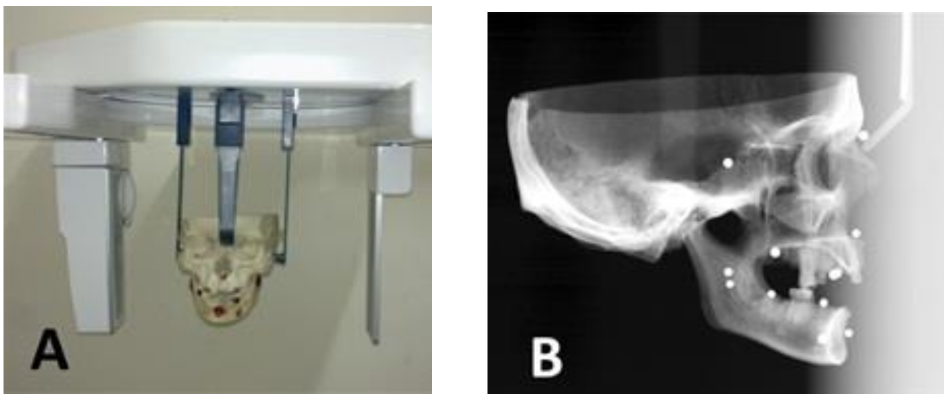

Figure (1): A- Positioning of skull containing metallic markers on the cephalostat. B- Cephalometric radiograph of skull showing the radiopaque markers.

According to the manufacturer instruction, the first measurements were calibrated by using the plastic stopper of the cephalostate containing a measuring strap to define a reference distance to calibrate the linear measurements and to remove any magnification resulted from geometric factor. While, the second measurements are taken without calibration. The magnification factor was calculated by a formula used to calculates the magnification rate[14];

The magnification rate = radiographic object length / actual object length.

The magnification factor calculated by dividing the non-calibrated radiographic measurements to the direct diameter of metallic balls. The mean value approximated to the nearest part of hundreds of millimeter which is equal to (1.08). Two radiopaque markers in the right and left upper premolar regions were excluded due to the superimposing of radiographic shadows on both sides.

Eight linear distances (N-ANS, ANS-Me, ANS-PNS, A-Pog, A-B, Ramus width, Go-Co, and Go-Me) connect cephalometric anatomical landmarks (Tables 2 & 3) measured directly on the five skulls by using a high-precision digital caliper calibrated to the nearest 0.01 mm (Figure 2) to be used as standard measurements[12,15]. Conventional cephalometric radiographs were taken for the five skulls with conventional cephalometric x-ray machine, type STRATO-M 505, model—2000, Italy which operated at 78 kVp, 8 mA and 0.8 sec. of exposure time. All the exposed radiographic films were processed manually in the darkroom at the room temperature (Figure 3).

Table (2): definition of the cephalometric landmarks.

No.	Landmarks	Definition
1	N -point	(Nasion): The most anterior point of the nasofrontal suture in the mid-sagittal plain[17].
2	ANS	Anterior Nasal Spine): The anterior tip of the sharp bony process of the maxilla[18].
3	PNS	(Posterior Nasal Spine): The posterior spine of the palatine bone consisting of the hard palate which coincides with the lowest point of the pterygomaxillary fissure (ptm)[19].
4	Me -point	(Menton): The lowest point on the symphyseal shadow of the mandible is seen on the lateral cephalogram[20].
5	Go –point	(Gonion): A midpoint of the angle of the mandible found by bisecting the angle formed by the mandibular and ramus plain[21].
6	Co -point	(Condylion): most superior point of head of condyle[22].
7	A -point	(Subspinale): The most posterior midline point overlying upper central incisors root apex in the concavity between the anterior nasal spine[22].
8	B -point	(Supramentale): The most posterior point in the outer contour of the mandibular alveolar process[22].
9	Pog -point	(Pogonion): The most anterior point on the bony chin[23].

Table (3): definition of the cephalometric linear distances.

No.	Linear distance	Definition
1	N-ANS	Nasion – Anterior nasal spine.
2	ANS-Me	Anterior nasal spine – Menton.
3	ANS-PNS	Distance between the anterior & posterior nasal spines.
4	A-Pog	Distance from A-point to Pogonion.
5	A-B	Distance between the A & B – points
6	Ramus width	Deepest points of the anterior & posterior aspects of the ascending Ramus.
7	Go-Co	Gonion – Condylon (Ramus height)
8	Go-Me	Gonion – Menton (Ramus length)

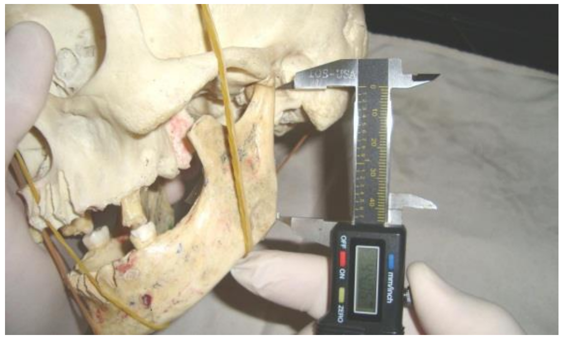

Figure (2): direct measurement of linear distances.

Figure (3): conventional cephalometric radiograph.

The same linear distance measured radiographically with conventional manual tracing[16]. The conventional radiographic linear measurements were divided by the estimated calibration factor (1.08), for additional evaluation. Then, the obtained direct conventional linear cephalometric measurements were compared with direct and calibrated linear cephalometric measurements. Statistical analysis; the data analyzed statistically with the paired sample *t*-test by SPSS software version 11.5.

RESULTS

The results showed a non-significant difference ($p > 0.05$) between the direct measurements diameters of radiopaque markers when compared with digitally calibrated radiographic measurement of their diameter in the X and Y axes ($p = 0.270$ and 0.413), and the calculated measurement of diameters by the using the defined calibration factor ($p = 0.617$ and 0.792). While, significant differences ($p < 0.05$) was found when compare the non-calibrated digital radiographic measurement of the markers diameters in X and Y axes with direct, calibrated radiographic and calculated radiographic measurements by the calibration factor ($p = 0.000$) (Table 4).

Table (4): comparison of the direct diameter measurement of radiopaque markers with other radiographic measurements methods in X & Y axes.

Group	Pairs	Group	Mean diff.	SD	*t*-value	*P*-value
X	1	Direct -calibrated	0.025	0.0672	1.176	0.270
	2	Direct - noncalibrated	-0.379	0.0152	-78.648	0.000
	3	Direct - factor	-0.007	0.0427	-0.518	0.617
	4	calibrated-noncalibrated	-0.404	0.0724	-17.634	0.000
	5	Calibrated- factor	-0.032	0.0882	-1.146	0.281
	6	Noncalibrated- factor	0.372	0.0473	24.855	0.000
Y	1	Direct -calibrated	0.009	0.0331	0.859	0.413
	2	Direct - noncalibrated	-0.354	0.0503	-22.222	0.000
	3	Direct - factor	-0.003	0.0349	-0.271	0.792
	4	calibrated-noncalibrated	-0.363	0.0539	-21.271	0.000
	5	Calibrated- factor	-0.012	0.0523	-0.712	0.494
	6	Noncalibrated- factor	0.351	0.0474	23.377	0.000

A significant difference was found between the direct anatomical linear and conventional cephalometric linear measurements. The same significant was found when compare the conventional cephalometric linear measurements with those measurements manipulated with the estimated calibration factor ($p < 0.05$) (Table 5). While, the comparison between direct and the calibrated linear cephalometric measurements was not significant ($p > 0.05$) (Table 5).

Table (5): comparison of the direct linear anatomical distances measurement with non-calibrated and calibrated conventional cephalometric measurements methods.

	Group	No.	Mean diff.	S.D	*t*-value	*P*-value
N-ANS	Direct - Noncalib	5	- 3.830	0.2090	- 40.968	0.000
	Direct - Factor	5	- 0.130	0.1977	- 1.470	0.215
	Noncalib - Factor	5	3.700	0.2230	37.093	0.000
ANS-Me	Direct - Noncalib	5	- 3.512	0.5375	- 14.609	0.000
	Direct - Factor	5	0.348	0.9625	0.808	0.464
	Noncalib - Factor	5	3.860	0.7684	11.232	0.000
Ramus width	Direct - Noncalib	5	- 4.062	0.4347	- 20.892	0.000
	Direct - Factor	5	- 0.306	0.5465	- 1.252	0.279
	Noncalib - Factor	5	3.756	0.8520	9.857	0.001
Go-Co	Direct - Noncalib	5	- 3.122	0.2728	- 25.590	0.000
	Direct - Factor	5	- 0.002	0.1229	- 0.036	0.973
	Noncalib - Factor	5	3.120	0.3727	18.716	0.000
ANS-	Direct - Noncalib	5	- 2.978	0.0491	- 135.36	0.000

PNS	Direct - Factor	5	0.018	0.1308	0.308	0.774
	Noncalib - Factor	5	2.996	0.1451	46.141	0.000
	Direct - Noncalib	5	- 2.754	0.4331	- 14.219	0.000
A-Pog	Direct - Factor	5	0.250	0.5719	0.977	0.384
	Noncalib - Factor	5	3.004	0.7060	9.513	0.001
	Direct - Noncalib	5	-3.294	0.4440	- 16.587	0.000
A-B	Direct - Factor	5	-0.068	0.1616	- 0.0941	0.400
	Noncalib - Factor	5	3.226	0.4085	17.658	0.000
	Direct - Noncalib	5	-3.500	0.5000	- 15.652	0.000
Go-Me	Direct Factor	5	0.198	0.5441	0.814	0.462
	Noncalib - Factor	5	3.698	0.7096	11.652	0.000

DISCUSSION

In clinical orthodontics, cephalometric analysis has long been used as an important clinical tool in diagnosis, treatment planning, and evaluation of growth or treatment results[4]. The dry skulls used in this study because the radiographs are taken lead to superior results compared to the clinical situation for reasons of standardization of exposure technique, keeping the same relation of the object to the image receptor and x-ray beam and obtain real direct measurements of the examined site[15,24]. In addition, the exposing human being to ionizing radiation for experimental study is a quite refuseable technique[25,26]. The metallic balls are preferred to be used as a radiopaque markers because the radiographic image of a metal ball has not been influenced by the geometrical conditions and parameters associated with an exposure (projection geometry) due to the symmetrical shape of the sphere[13,27,28]. Because, the magnification is not constant for all possible sagittal plains of the object, where, the structures located closer to the image receptor will present lower magnification comparing to those closer to the rays. Therefore, the markers fixed at a different sagittal plains from the image receptor[29]. There is still a magnification with lateral cephalograms lead to the variation in magnification especially with linear measurements[7,8]. In the present study the calibrated digital linear measurements show non-significant difference with direct linear measurements. While, the conventional linear cephalometric measurements showed a significant difference as compared with those direct measurements, these findings supported by the studies[30,31,32,33] of Gayatri *et al*.,; Agrawal *et al*.,; Salman and Muhammad; and Tanwani *et al*.,. This significance between the conventional and direct linear measurements was reduced by the use to estimated calibration factor (1.08) to eliminate the linear image magnification. This come in agreement with Zecca *et al*.[34]; and Kamath and Arun[35] studies; they showed that magnification values reported by the manufacturer might not correspond to the calculated magnification values in the different sagittal plains. In controversy, the other studies showed that the linear measurements gained by digital lateral cephalometric radiographies, were comparable to non-calibrated linear measurements obtained from conventional radiographies[36,37,38].

In a study by Spolyar,[39] observed a mean linear change of 1.7 mm ranging from 0.5 to 6.2 mm. According to Weems[40] magnification of craniofacial structures varies from almost 0% up to 24% in objects close to the film or objects in the exact center of the rays, where the manual conventional cephalometric linear measurements were used directly without calibration. This magnification is not constant for all possible sagittal plain of patient. Structures located closer to the film presented lower magnification comparing to those closer to the rays. Therefore, the use of estimated calibration factor makes the manual conventional cephalometric linear measurements reliable as that obtained from digital measurements by reduce or eliminate the inherent rate of linear magnification. Where, the advanced digital imaging modalities are required machine with specified software that are readily still limited to large town centers making the admittance to this technology is quite limited for most of the dental practices. In addition to the high cost of examinations, and the need of expert staff for interpretation of complex images, lead to select a clinical planning based on conventional radiographic images[41,42,43]. In addition to that the radiographic film it is quite stable and can retain information for many years, due to its physical nature[7,8]. Thus hand-traced cephalometric analysis on traditional radiographic images have been for many years as the gold standard for analyzing a cephalometric radiograph and collecting cephalometric values[44,45]. This facilitates the use of conventional cephalometric radiograph from the old patients archiving in the longitudinal studies.

CONCLUSION

The present study finds that the conventional cephalometric linear measurements could be accurate as that of digital cephalometric linear measurements, if it's calibrated by the calibration factor (1.08) which is estimated by the present study.

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