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# Evaluation of Reliability of Quadraceph Software for Cephalometric Analysis

Dr. Praveen Kumar [1], Dr. Vasu Murthy Sesham [2],
Nikitha Reddy Patel[3], Dr.Pavan Kumar Mamillaplli[4]
[1]*Professor, Department of Orthodontics, Kamineni Institute of Dental Sciences, Narketpally.*
[2]*Professor & Head, Department of Orthodontics, Kamineni Institute of Dental Sciences, Narketpally.*
[3] *Former Resident, Department of Orthodontics, Kamineni Institute of Dental Sciences, Narketpally.*
[4]*Professor, Department of Orthodontics, Kamineni Institute of Dental Sciences, Narketpally.*
*Corresponding Author: Dr. Praveen Kumar*

***Abstract:***
***Aim:*** *To evaluate the reliability of Quadraceph Software for cephalometric analysis*
***Materials and methods****: The study was conducted on pre-treatment cephalometric radiographs of 25 patients. The digital tracing was done using Quadraceph Imaging Software. A total of 26 landmarks were defined on each Cephalogram. Out of 25 radiographs 15 were retraced manually and digitally for investigating the reliability (intraexaminer error) and the reproducibility for the manual and digital method.*
***Conclusion:*** *Greater variability in repeated cephalometric measurements was found in tracings done with Quadraceph Software compared with manually traced images. The differences, however, were statistically insignificant.*

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## I. Introduction:

Cephalometric radiography is an essential tool in the diagnosis and treatment of dental malocclusions and underlying skeletal discrepancies. [1]

Conventional cephalometric analysis is performed by tracing radiographic landmarks on acetate overlays and measuring linear and angular values. Despite its widespread use in orthodontics, the technique is time consuming. With the rapid evolution of computer radiography, digital tracing has slowly replaced the manual tracing methods.

For digital cephalometry to be a better tool in clinical orthodontics, the cephalometric analysis represented by widely used linear and angular measurements, must be as comparable as it is on a conventional radiographic film.Hence Software used for cephalometric analysis should be reliable.

**AIM & OBJECTIVE**
To evaluate the reliability of Quadraceph Software for cephalometric analysis

## II. Materials And Methods:

The study was conducted on pre-treatment cephalometric radiographs of 25 patients collected from the archives of the outpatient clinic of the orthodontics department, Kamineni Institute of Dental Sciences, Narketpally.

No differentiation was made for age or gender. Only good-quality radiographs without any artefacts were selected. The same machine was used to obtain all the radiographs.

All participants were positioned in the cephalostat with the sagittal plane at a right angle to the path of the X-rays, the Frankfort plane parallel to the floor, the teeth in centric occlusion and the lips sealed lightly together. The conventional and digital tracings as well as all the measurements were performed. Manual tracing was performed on fine-grain 0.003 inch transparent acetate papers using a 0.3 mm lead pencil. The tracing process was performed in a dark room using a screen viewing box. All measurements were carried out manually and entered into an Excel spreadsheet for statistical evaluation.

The digital tracing was done using Quadraceph Imaging Software. Once captured using the software, calibration of the actual size of each image in millimeters was based on the measurement of the known distance (100 mm) between the two fixed points of the Quadraceph ruler on the screen. This calibration standardized all

images. Landmark identification was carried out manually on digital images using a mouse-driven cursor and then stored in the Quadraceph Imaging archive. A total of 26 landmarks were defined on each cephalogram that are shown in table-I.

Out of 25 radiographs 15 were retraced manually and digitally at a 6-week interval for investigating the reliability (intra-examiner error) and the reproducibility for the manual and digital method

## III. Statistical Analysis

Examiner error (reliability) was evaluated by duplicating tracings of 15 radiographs (performed a minimum of 2 weeks apart) and using the Pearson correlation coefficient as a measure of standardized covariance(Table-II).Systematic error (reproducibility) was calculated by paired measurement comparisons of the 25 digital and manual tracings by using paired t-tests based on equality of variance between the 2 samples A P-value of 0.05 was used as the minimal level of statistical significance (Table-III).

In this study the mean difference between the manual tracings as gold standard and the digital tracings was determined for each parameter. Because a difference of 2 degree or 2 mm in means does not appear to cause a clinical difference in classification or treatment decisions in most of the parameters, any difference less than 2 units was considered to be clinically acceptable.

**Table I: Selected Cephalometric measurements**.

| S.no | Measurement | Unit | Definition |
|---|---|---|---|
| 1 | SNA | ˚ | Angle between SN and NA |
| 2 | SNB | ˚ | Angle between SN and NB |
| 3 | ANB | ˚ | Angle between NA and NB |
| 4 | SNMP | ˚ | Angle between SN and MP |
| 5 | UINA(D) | ˚ | Angle between long axis of upper incisor and NA |
| 6 | UINA(L) | mm | Linear distance between incisal edge of upper incisor and NA |
| 7 | LINB(D) | ˚ | Angle between long axis of lower incisor and NB |
| 8 | LINB(L) | mm | Linear distance between incisal edge of lower incisor and NB |
| 9 | IIA | ˚ | Angle between long axis of upper incisor and long axis of lower incisor |
| 10 | UL-S LINE | mm | Linear distance between upper lip and S-line |
| 11 | LL-S LINE | mm | Linear distance between lower lip and S-line |
| 12 | LL-E PLANE | mm | Linear distance between lower lip and E- plane |
| 13 | FMA | ˚ | Angle between FH-plane and MP |
| 14 | IMPA | ˚ | Angle between long axis of lower incisor and MP |
| 15 | A-B on OP | mm | Linear distance between AO-BO |
| 16 | Nasolabial angle | ˚ | Angle between a line tangent to the base of the nose and a line tangent to the upper lip |
| 17 | Co-A | mm | Linear distance between condylion to point –A (maxillary base length) |
| 18 | Co-Gn | mm | Linear distance between condylion to Gn(mandibular base length) |
| 19 | Max-Man | mm | Difference between maxillary base length and mandibular base length |
| 20 | Basic upper lip thickness | mm | Horizontal distance from a point on outer cortex 1mm above point A to outer surface of lip |
| 21 | Upper lip strain | mm | Difference between a horizontal measurement from vermillion border of lip to labial surface of maxillary incisor to basic upper lip thickness |
| 22 | Beta angle | ˚ | Angle between perpendicular from point A on Co-point B to AB-line |
| 23 | Sum of angles | ˚ | Sum of angles between (SN-NAr), (NAr-ArGo) and (ArGo-MeGo) |
| 24 | Ramus height | mm | Linear distance between Ar to Go |
| 25 | PFH-AFH% | % | Posterior facial height (Se-Go)X100 / Anterio facial height (N-Me) |
| 26 | UI-SN | ˚ | Angle between long axis of upper incisor to SN plane |

*For more accurate identification in this study we use co point instead of Po.8

**Table II: Differences in paired measurements for digital and conventional radiographs (reliability)**

| S.no | Measurement | Manual method | | | | Quadraceph | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Difference | | Coefficient of determination | | Difference | | Coefficient of determination | |
| | | Mean | SD | | | Mean | SD | | |
| 1 | SNA | 0.4 | -0.41 | 0.77 | | 0.77 | -0.14 | 0.82 | |
| 2 | SNB | -2.4 | 8.83 | 0.08 | | 0.58 | -0.23 | 0.92 | |
| 3 | ANB | -0.8 | 0.49 | 0.59 | | 0.17 | 0.55 | 0.65 | |
| 4 | SNMP | 1 | -0.23 | 0.92 | | -0.3 | -0.02 | 0.95 | |
| 5 | UINA(D) | -0.4 | -0.42 | 0.88 | | -0.4 | 0.40 | 0.88 | |
| 6 | UINA(L) | 0.13 | 0.15 | 0.81 | | -0.6 | 0.26 | 0.68 | |
| 7 | LINB(D) | 1.86 | -0.73 | 0.9 | | -1.9 | 0.00 | 0.59 | |
| 8 | LINB(L) | 0.66 | -0.24 | 0.82 | | -0.1 | 0.24 | 0.72 | |
| 9 | IIA | -2.86 | 1.43 | 0.77 | | 8.4 | -15.39 | 0.01 | |
| 10 | UL-S LINE | 0.53 | -0.04 | 0.78 | | 0.08 | 0.10 | 0.75 | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 11 | LL-S LINE | 0.4 | -0.32 | 0.64 | | 0.34 | -0.38 | 0.6 |
| 12 | LL-E PLANE | 0.16 | -0.26 | 0.94 | | -0.18 | -0.05 | 0.95 |
| 13 | FMA | 0.66 | -1.08 | 0.87 | | 0.28 | -0.13 | 0.83 |
| 14 | IMPA | 7 | 20.70 | 0.19 | | -1.11 | 0.91 | 0.41 |
| 15 | A-B on OP | 0.33 | 0.98 | 0.74 | | 0.66 | 0.55 | 0.8 |
| 16 | Nasolabial angle | 5.13 | -1.77 | 0.52 | | 0.24 | 0.45 | 0.78 |
| 17 | Co-A | 0.13 | 0.54 | 0.82 | | -0.1 | -0.25 | 0.91 |
| 18 | Co-Gn | 0.4 | -0.69 | 0.86 | | 0.08 | -0.31 | 0.9 |
| 19 | Max-Man | -0.66 | -1.16 | 0.32 | | 0.32 | 1.22 | 0.87 |
| 20 | Basic upper lip thickness | -1.53 | 0.06 | 0.24 | | -0.46 | 0.13 | 0.85 |
| 21 | Upper lip strain | 1.73 | 0.69 | 0.26 | | -0.12 | 0.25 | 0.62 |
| 22 | Beta angle | 0.06 | -0.34 | 0.85 | | 0.74 | 1.28 | 0.91 |
| 23 | Sum of angles | -1 | -0.35 | 0.65 | | -0.78 | 0.29 | 0.95 |
| 24 | Ramus height | -0.5 | -0.11 | 0.74 | | -0.36 | 0.85 | 0.8 |
| 25 | PFH-AFH% | -0.15 | -0.27 | 0.91 | | 0.68 | -0.13 | 0.41 |
| 26 | UI-SN | 0.2 | -0.61 | 0.84 | | 0.85 | -0.03 | 0.89 |

*Low correlation between repeated measures.*Differences of mean measurements exceeding 2 units (clinically significant).

**Table III: Measurement differences between digital and manual tracings**.

| SNO | MEASUREMENT | DIFFERENCE | | P VALUE |
|---|---|---|---|---|
| | | MEAN | SE | |
| 1 | SNA | 0.59 | 0.08 | 0.68 |
| 2 | SNB | -1.34 | 1.33 | 0.59 |
| 3 | ANB | 0.26 | 0.05 | 0.69 |
| 4 | SNMP | 3.02 | 2.68 | 0.47 |
| 5 | UINA(D) | -1.49 | -0.16 | 0.41 |
| 6 | UINA(L) | -0.53 | 0.09 | 0.52 |
| 7 | LINB(D) | -1.33 | 0.12 | 0.45 |
| 8 | LINB(L) | -0.11 | -0.07 | 0.88 |
| 9 | IIA | 0.5 | 0.45 | 0.86 |
| 10 | UL-S LINE | 1.32 | 0.05 | 0.00 |
| 11 | LL-S LINE | 0.46 | 0.05 | 0.47 |
| 12 | LL-E PLANE | 0.16 | -0.01 | 0.77 |
| 13 | FMA | -3.26 | -0.05 | 0.06 |
| 14 | IMPA | 5.3 | 3.11 | 0.25 |
| 15 | A-B on OP | -0.63 | -0.15 | 0.49 |
| 16 | Nasolabial angle | -2.76 | -0.08 | 0.36 |
| 17 | Co-A | 0.38 | -0.07 | 0.82 |
| 18 | Co-Gn | -0.3 | -0.11 | 0.91 |
| 19 | Max-Man | 2.69 | 2.69 | 0.51 |
| 20 | Basic upper lip thickness | -3.04 | -0.02 | 0.00 |
| 21 | Upper lip strain | 0.56 | 0.03 | 0.27 |
| 22 | Beta angle | -0.9 | -0.01 | 0.59 |
| 23 | Sum of angles | 0.92 | 0.06 | 0.59 |
| 24 | Ramus height | 0.24 | 0.17 | 0.87 |
| 25 | PFH-AFH% | 0.26 | 0.11 | 0.86 |
| 26 | UI-SN | -0.12 | 0.05 | 0.96 |

*Statistically significant difference between two methods ($p<0.05$)
*Differences of mean measurements exceeding 2 units (clinically significant).

## IV. Results:

Table-II indicates the reliability of repeated measurements by a single operator for two methods investigated. The differences between the means of the 2 samples are also shown. Greater differences were detected for repeated measurements performed with the digital method .Differences between the first and second tracings varied between -2.86 and 5.13 units (millimeters, degrees or percent according to the measurements) for manual tracings and between -1.9 and 8.4 for digital ones. Variability of the differences was reflected in the coefficients of determination (r2) that if more than 0.5, means good reproducibility of the variable (good reliability). For manual tracings, the coefficient of determinations of all variables were above 0.5 with the exception of SNB (0.08), IMPA (0.19), Max-Man (0.32), basic upper lip thickness (0.24), upper lip strain (0.26) . For the digital method, we obtained three measurements with an r2 below 0.5, IIA (0.01), IMPA (0.41), PFH-AFH% (0.41). Overall, the comparison between r2 values showed good reliability and a small error of the operator for all measurements.

Table III gives the measurement differences between the 2 methods. In general, the magnitude of the difference between sample means was small, with only 5 measurements (SN-MP, FMA, Nasolabial angle, Max-

Man, basic upper lip thickness) having values above 2 units (millimeter, degree or percent). Statistically significant differences were detected for UL-S line, basic upper lip thickness.

## V. Discussion

Reliability is an important aspect of measurement. If a measure cannot be reproduced consistently, then the value (cost, time and patient treatment decisions) of the methodology is questionable. In a clinical situation such as in orthodontics, a reproducibility that is within 2mm will probably not make a difference in treatment.[2] The analysis of the error (coefficient of determination,table-II) on the conventional tracing showed a high correlation of repeated measures, meaning that the operator had no difficulty in correctly reproducing measurements on traditional procedure and that the landmarks were readily identifiable. Subjective assessment of image quality can predict reliability of the landmark location allow value of the coefficient of determination values for few parameters in both manual and digital methods were found to be below 0.5 indicating poor reproducibility[3]. Since radiographic images with better contrast used in this research were taken by analogue machines, in spite of effort to select better contrast images, however it was possible to have some cases with undetectable borders of soft tissues. Another factor is that the definition of the landmark relates to anatomic variability of landmark location. A sharp incisal edge would likely have less error associated with its identification than a landmark location, associated with a more gradual curve such as Sn point.Errors in the latter would be influenced by the vertical or horizontal orientation of the curve. In addition, it is also based on authors experience.[4]

Landmark identification is greatly affected by the operator's experience, which might be as important as the tracing method itself. Inter-examiner error has been found in general to be greater than intra-observer error, so that to minimize errors, all measurements in this study were made by 1 examiner. Our data on reliability of hand traced measurements were similar to those obtained in other studies.[5,6,7]

Landmark identification from digital images can be affected by several factors such as spiritual and contrast resolution of the display device, background luminance level, and luminance range of the display system, brightness, uniformity, extraneous light in the reading room, displayed field size, viewing distance, image motion and monitor, flickering, signal-to-noise ratio of the displayed images, magnification functions, and user interface. In regard to the digital measurements in our body, reliability was also generally satisfactory, with only the IIA (0.01), IMPA (0.41), PFH-AFH% (0.41) having significant mean differences.

Our results indicate that the reliability of repeated measurements appears to be acceptable in both methods except for few values and that it is slightly better with conventional tracing than with digital tracing software, corroborating the findings of previous studies. [5,8,9]

Utilization of Software aided cephalometric analysis can be justified only through the repetitive examination of outcome measurements showing at least comparable or perfectly improved accuracy when compared with that of traditional manual technique.

Table III represents the results of the comparison, via paired t-test, between the digital and manual methods. The statistically significant differences detected for 5 of the 26 cephalometric variables (SN-MP, FMA, Nasolabial angle, Max-Man, basic upper lip thickness. The problems encountered for the mandibular plane for Sn-Mp and FMA, mandibular length for max-man difference can be explained by difficulty in locating the gonion. This point corresponds to a poorly defined outline associated with bilateral anatomic structures, located away from the mid sagittal plane and often projecting as a double image on the film. It is difficult to define the bilateral landmarks. Identification of this landmark can be facilitated by constructing the point and using the bisecting angle to a tangent to the posterior border of the ramus and the mandibular plane, unfortunately, this could not be done with Quadraceph tracing software.

The nasolabial angle is formed by drawing a line tangent to the base of the nose and a line tangent to the upper lip. Since radiographic images with better contrast used in this research were taken by analogue machines, in spite of effort to select better contrast images, however; it was possible to have some cases with undetectable borders of soft tissues. Another factor is that the definition of the landmark relates to anatomical variability of the landmark location. A sharp incisal edge would likely have less difference associated with its identification than a landmark location associated with a more gradual curve such as Sn point. Difference in the later would be influenced by the vertical or horizontal orientation on the curve. In addition, based on author experience, drawing the tangent line from the Sn point to the base of the nose in digital method is not so accurate and reliable.

Basic upper lip thickness is horizontal distance from a point on outer cortex 1mm above point A to outer surface of lip. Hence in similar manner as soft tissue landmark identification is effected in case of nasolabial angle this is also effected.

As technology progresses, it becomes increasingly difficult to determine if there is adequate evidence to access the efficacy of the technology before it becomes commercially available. Although a multitude of cephalometric analysis software programs are available on market for several years, there are few studies

comparing their reliability and the similarity of measures across the programs. There are also few studies determining if there are differences between different versions of cephalometric analysis software[10]. It can be difficult for the practitioner to select technology that is reliable and accurate unless appropriate studies are available. This study provides a basis for evaluation of the software programs. Further studies in this area will, no doubt, improve our knowledge about the risks and limitations of other software. But, for the time being, the orthodontic office can depend on Quadraceph software for lateral cephalometric analysis and diagnosis with knowledge of its little deficiencies.

## VI. Summary And Conclusion:

- Greater variability in repeated cephalometric measurements was found in digital method compared with manually traced images. The differences, however, were clinically insignificant, because for most values, the mean differences were near or lower than2 units. Both the hand-traced and the digital method therefore can be safely regarded as reliable.
- When comparing the 2methods, the difference between means individual measurements was rarely above 2mm, 2degrees, or 2%, except only some measurements of difficult to locate landmarks, especially Gonion point and Nasolabial angle. The data suggest that Quadraceph tracing software can be used instead of time consuming conventional method for lateral cephalometric analysis with knowledge of its limited errors.

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