Reproducibility of Manual and On-Screen Digital Cephalometric Tracing for Soft-Tissue Profile Variables: A Comparative Retrospective Study

Manju Krishnan P (PG Resident)[1], Tojan Chacko (Professor)[2], Jose Jacob (Professor & HOD)[3], Supriya Gopalakrishnan (Professor)[4], Anuradha (Reader)[5], Vineetha Menon (Reader)[6], Midhun Raghav (Reader)[7],8 Pooja Sanal (Senior Lecture)[8]
Department of Orthodontics and Dentofacial Orthopaedics, Sree Anjaneya Institute of Dental Sciences, Kozhikode, Kerala, India

***Abstract*—Cephalometric analysis is an important component of orthodontic diagnosis and treatment planning. Although manual tracing has traditionally been used, digital cephalometric analysis offers advantages in image manipulation, measurement, data storage and workflow efficiency. The reproducibility of soft-tissue measurements remains a concern because many soft-tissue landmarks have indistinct radiographic boundaries.**

Aim: To compare the reproducibility of manual tracing and on-screen digitalisation for soft-tissue cephalometric variables.

***Materials and Methods:* This retrospective observational study included pretreatment lateral cephalograms of 60 patients aged 14–27 years with a skeletal Class I relationship. Radiographs were obtained under standardized conditions with the patient in natural head position and lips at rest. Soft-tissue cephalometric variables involving the lips, nose, chin and facial profile were assessed by two observers using conventional manual tracing and on-screen digitalisation with NemoCeph software. Data distribution was assessed using the Shapiro–Wilk test, and manual and digital measurements were compared using paired t-tests.**

***Results:* No statistically significant differences were found between manual and digital measurements for any of the evaluated soft-tissue variables ($p > 0.05$). Both methods demonstrated high intra- and inter-examiner reproducibility. Angular variables, including the H angle, Z angle and nasolabial angle, showed greater consistency than several linear soft-tissue measurements. Greater variability was observed in perioral variables, particularly lower-lip measurements, interlabial gap and soft-tissue pogonion. Digital tracing showed comparable or slightly lower variability for several measurements.**

***Conclusion:* On-screen digital cephalometric tracing using NemoCeph demonstrated measurement outcomes comparable with conventional manual tracing and may be considered a reliable alternative for soft-tissue cephalometric analysis. However, digitalisation does not eliminate variability associated with soft-tissue landmark identification. Particular care is required when interpreting perioral measurements and other parameters that are sensitive to small landmark-position differences.**

***Index Terms*—Cephalometry; digital tracing; manual tracing; soft-tissue analysis; reproducibility; NemoCeph; orthodontics**

I. INTRODUCTION

Cephalometric analysis has been an integral part of orthodontic diagnosis, treatment planning and evaluation of treatment outcomes since the introduction of standardized lateral cephalometry.[1] Although early analyses focused predominantly on skeletal and dental relationships, soft-tissue evaluation has become increasingly important because facial aesthetics and treatment outcomes cannot be predicted solely from hard-tissue relationships.[2]

Manual cephalometric tracing remains a commonly used method but is influenced by landmark identification, operator experience and tracing-related errors. Landmark identification is considered an important source of cephalometric measurement error, with soft-tissue landmarks generally being more difficult to identify because of their diffuse radiographic boundaries.[3]

Computer-assisted and digital cephalometric systems were introduced to improve efficiency, facilitate

image enhancement and automate measurement calculations[6]. Previous studies have generally demonstrated comparable measurements between manual and digital methods, although differences may occur for individual landmarks and measurement types.Dvortsin et al. reported comparable reproducibility between manual and digital tracing, with digital tracing showing slightly improved consistency for some variables[5].

Despite increasing adoption of digital workflows, the reproducibility of soft-tissue profile measurements remains particularly relevant because small differences in lip and facial-profile measurements may influence orthodontic and aesthetic treatment decisions. Therefore, the present study compared manual and on-screen digitalisation of soft-tissue cephalometric variables and evaluated observer-related variability4.

II. AIM

To evaluate and compare the reproducibility of manual tracing and on-screen digitalisation for soft-tissue cephalometric variables.

III. MATERIALS AND METHODS

Study design and sample

A retrospective observational study was conducted in the Department of Orthodontics and Dentofacial Orthopaedics, Sree Anjaneya Institute of Dental Sciences, Ulliyeri, Kozhikode. Pretreatment lateral cephalograms of 60 patients aged 14–27 years with skeletal Class I relationships were selected. The sample size was based on previous literature concerning the reproducibility of manual and digital cephalometric tracing.[7]

Patients with previous orthodontic treatment, skeletal Class II or Class III relationships, craniofacial deformities or incomplete soft-tissue profiles were excluded.

Radiographic procedure

Digital lateral cephalograms were obtained under standardized conditions using the same cephalostat. Radiographs were recorded in maximum intercuspation with the lips at rest. Natural head position was maintained with the Frankfort horizontal plane parallel to the floor[8].

Cephalometric analysis

The selected cephalograms were analysed using two methods:

1. Manual tracing: Cephalograms were traced on acetate tracing material using conventional cephalometric procedures.
2. Digital tracing: The same radiographs were digitised and analysed using NemoCeph software.

Two independent observers performed the measurements using both methods. The evaluated variables represented the upper and lower lips, interlabial region, facial profile, nose, chin and projection measurements. These included lip prominence, lip thickness, lip curvature, lip strain, sulcus depth, interlabial gap, H-line and H-angle measurements, E-line and S-line measurements, Z-angle, nasolabial angle, chin prominence, soft-tissue chin thickness and soft-tissue A point, B point and pogonion projections.

Statistical analysis

Normality was assessed using the Shapiro–Wilk test. Manual and digital measurements were compared using paired t-tests. A p value <0.05 was considered statistically significant.

Results

The measurements demonstrated a normal distribution. No statistically significant difference was observed between manual and digital measurements for any of the evaluated variables ($p > 0.05$).

The mean values obtained by the two techniques were closely comparable. Representative measurements included:

Variable	Manual mean	Digital mean
St- incisal edge	4.93 mm	4.96 mm
Upper – lip prominence	4.83 mm	4.92 mm
Upper – lip curvature	3.36 mm	3.41 mm

Upper – lip thickness	16.25 mm	16.26 mm
Lower – lip prominence	5.01 mm	4.97 mm
Lower – lip depth	4.21 mm	4.27 mm
Interlabial gap	4.76 mm	4.79 mm
H angle	17.69°	17.67°
Z angle	69.59°	69.83°
Nasolabial angle	85.74°	85.85°
Soft – tissue chin thickness	10.98 mm	10.97 mm
Soft – tissue pogonion	6.12 mm	5.98 mm

The differences between the two techniques were small and statistically nonsignificant.

Both methods demonstrated high intra- and inter-examiner reproducibility. However, variability was greater for several perioral landmarks, particularly lower-lip prominence, lower-lip depth, interlabial gap and soft-tissue pogonion. Angular measurements generally demonstrated greater reproducibility than linear soft-tissue measurements.

IV. DISCUSSION

The principal finding of this study was that manual and digital tracing produced comparable soft-tissue cephalometric measurements, with no statistically significant differences for any of the evaluated variables. This supports the clinical interchangeability of the two methods for the measurements investigated.

The findings are consistent with Dvortsin et al., who reported comparable reproducibility between manual and digital tracing and suggested that on-screen digitisation may provide slightly improved reproducibility for selected soft-tissue variables.[8] Previous investigations have similarly reported clinically acceptable agreement between conventional and computerized cephalometric methods.[8,9,10]

An important finding was the persistence of variability in specific soft-tissue landmarks despite the use of digital analysis. The perioral region, particularly the lower lip and interlabial area, demonstrated greater measurement variability. This is consistent with previous research showing that landmark identification is a major source of cephalometric error and that soft-tissue landmarks are generally less reproducible because of their diffuse anatomical boundaries.[5,6]

Angular measurements such as the H angle, Z angle and nasolabial angle were relatively more reproducible than linear soft-tissue measurements. This observation is consistent with the established principle that angular measurements may be less sensitive to small positional errors in individual landmarks than linear measurements.[11]

The present study also demonstrated comparable or slightly improved consistency with digital tracing for several variables. Digital systems allow magnification, image enhancement and direct computer-based measurement, which may facilitate landmark identification and reduce some sources of manual measurement error.[7,8] Nevertheless, digitalisation should not be interpreted as eliminating observer-dependent error. The identification of soft-tissue landmarks remains dependent on anatomical definition, image quality and examiner experience.

The clinical relevance of small differences should also be considered. Although the observed differences were statistically nonsignificant, several soft-tissue variables demonstrated differences within approximately 0.5–2 mm. Such differences may be relevant in borderline aesthetic assessments, particularly when treatment decisions depend on subtle changes in lip position or facial profile.

V. CLINICAL IMPLICATIONS

The findings support the use of digital cephalometric analysis as a practical alternative to manual tracing for routine soft-tissue assessment. Digital analysis may be particularly advantageous in contemporary orthodontic practice because of easier image manipulation, measurement, storage and retrieval. However, clinicians should avoid relying exclusively on automated or digital measurements when landmarks are poorly defined, especially in the perioral region.

VI. LIMITATIONS

The study was retrospective and included patients with skeletal Class I relationships within a relatively restricted age range. Only lateral two-dimensional cephalograms were evaluated, and the study focused on a single digital platform. Therefore, the findings should not necessarily be extrapolated to other software systems, three-dimensional imaging modalities or different skeletal patterns.

VII. CONCLUSION

Within the limitations of this study, manual and on-screen digital cephalometric tracing produced comparable measurements for the evaluated soft-tissue variables, with no statistically significant differences between the two methods. Both techniques demonstrated good reproducibility. Digital tracing using NemoCeph may therefore be considered a reliable and clinically acceptable alternative to conventional manual tracing.

However, soft-tissue landmark identification remains an important source of variability, particularly for perioral landmarks such as the lower lip and soft-tissue pogonion. Digital technology improves efficiency and may enhance measurement consistency, but careful landmark identification and examiner expertise remain essential for reliable soft-tissue cephalometric analysis.

REFERENCES

[1] Broadbent BH. A new X-ray technique and its application to orthodontia. Angle Orthod. 1931;1(2):45–66.
[2] Hofrath H. Die Bedeutung der Röntgenfern- und Abstandsaufnahme für die Diagnostik der Kieferanomalien. Fortschr Orthod. 1931; 1:232–248.
[3] Subtelny RL. The soft tissue profile, growth and treatment changes. Angle Orthod. 1961;31(2):105–122.
[4] Arnett GW, Bergman RT. Facial keys to orthodontic diagnosis and treatment planning—Part I. Am J Orthod Dentofacial Orthop. 1999;115(3):239–253.
[5] Baumrind S, Frantz RC. The reliability of head film measurements: landmark identification. Am J Orthod. 1971;60(2):111–127.
[6] Trpkova B, Major P, Prasad N, Nebbe B. Cephalometric landmarks identification and reproducibility: a meta-analysis. Am J Orthod Dentofacial Orthop. 1997;112(2):165–170.
[7] Sayinsu K, Isik F, Trakyali G, Arun T. An evaluation of the errors in cephalometric measurements on scanned cephalometric images. Eur J Orthod. 2007;29(5):488–493.
[8] Dvortsin V, Sandham A, Pruim GJ. A comparison of the reproducibility of manual and digital cephalometric tracing. Eur J Orthod. 2008;30(6):586–591.