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Original Research Article

Comparison of Reliability and Efficiency of Down's and Steiner's Cephalometric Analysis between Digital and Conventional Methods

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Abstract

Objective: To compare the reliability and efficiency of Down's and Steiner's cephalometric analysis between conventional method and digital method using the CephNinja application. ***Materials and Methods:*** 50 lateral cephalograms were used. Down's and Steiner's cephalometric analyses were carried out using the conventional method and digital method using a mobile application, CephNinja. Values and time taken for the analyses were recorded for both manual and digital methods. Non-parametric test (Wilcoxon matched test) and parametric test (paired t test) were carried out. A correlation between values of manual and digital methods were carried out using Karl Pearson's correlation method. ***Results:*** Comparison of manual and digital methods with parameters related to Down's analysis by paired t / Wilcoxon matched pairs test showed significant differences in interincisal angle, lower incisor to occlusal plane angle and time scores. The mean time taken for manual cephalometric analysis was 4.86 minutes while the digital method took 2.18 minutes. Paired t / Wilcoxon matched pairs test for comparison of manual and digital method in Steiner's analysis showed significant differences in mandibular plane angle, linear measurement for upper incisor position, S-line to upper lip, and time scores. The mean time taken for manual took 4.1 minutes and CephNinja was 2.14 minutes. Significant correlation using Karl Pearson's method was seen between manual and digital methods except in the values of Y-axis and S-line to upper lip. ***Conclusion:*** CephNinja app is as reliable as the conventional method and significantly reduces the time taken for carrying out Down's and Steiner's analyses.

Keywords: CephNinja, Cephalometrics, Down's Analysis, Steiner's Analysis, Conventional Cephalometrics, Digital Cephalometrics.

INTRODUCTION

Radiography in the field of dentistry has been revolutionised ever since Roentgen made the discovery of X-rays in 1895. Only in 1931, a cephalostat which uses a high-powered X-ray machine and a head holder was introduced whereby a standardised cephalometric technique can be created. This was simultaneously introduced by Broadbent in the United States of America and Hofrath in Germany. Cephalometrics have influenced orthodontics in ways such as growth analysis of patients can be compared, appreciations of alterations prior and after orthodontic therapy and most importantly a morphological analysis of sagittal and vertical relations of the dentition, facial skeleton and soft tissue profile [1].

Since there was great progression towards a standardised cephalometric technique, many clinicians had pioneered ways to analyse the discrepancies between the dentition, jaw bases and the surrounding soft tissues using the cephalograms. Down's in 1948 had introduced the first complete analysis which compares the dental relationships, relationship of maxilla and mandible to each other as well as to the cranium. He had advocated the use of the Frankfort Horizontal plane as a reference plane due to its clinical visibility and familiarity to clinicians [1, 2]. Many more analysis had been made from that moment on with Cecil Steiner's analysis being a very well-known analysis among them. His analysis was among the first use of the sella-nasion plane as a reference plane. This analysis was simple and easy to use and had also compared the dental, skeletal and the lips in the soft tissue components [1, 3].

Over the last couple of decades, there has been a great advancement of technology in that has changed our personal lives and our professional field. The rise of

the smartphones has lead to a great deal of use in the medical and dental field. There is a flurry of applications or 'apps' in the smartphones and tablets that have cater to both patients' and doctors' needs. In the field of orthodontics, several apps have been introduced such as Progressive Orthodontics app that help in business and practice management, Carriere Ortho 3D app that are meant for its products and patient education, Bolton Calc app that are tooth width ratio calculators, and Rubber-band Reminder app to remind patients to wear their elastics. These are just a few apps of the many orthodontic apps that exist [4, 5].

There are two methods that cephalometric analysis can be done which are the conventional methods by manual tracing and computerised digital methods. The conventional method is done by manual tracing in which an acetate sheet is placed over the cephalogram and is traced on it. The radiographic landmarks are marked on the acetate sheet and with the help of rulers and protractors, angular measurements and linear measurements are measured. Conventional methods take up more time than computerised digital methods [6, 7]. Computerised digital method using a software program in which the landmarks and lines are marked. These software then analyses the cephalogram with the marked landmarks to process a particular cephalometric analysis of choice [7, 8]. Many software and apps are available such as SmartCeph Pro app, Dolphin Imaging software, and CephNinja app just to name a few [9].

The aim of this study was to compare measurements using Down's and Steiner's cephalometric analysis with the CephNinja app and conventional cephalometric method. The study will also be comparing the time taken for carrying out Down's and Steiner's analysis between the conventional cephalometric method and with the CephNinja app to demonstrate any difference in the efficiency of both methods.

MATERIALS AND METHODS

In this study, 50 lateral cephalograms of patients were used. The distribution of male and female patient was randomly distributed. Digital cephalograms of the same lateral cephalograms were taken in a JPEG format. The list of research tools that were used are 0.3mm Pentel Graphgear 500 mechanical pencil, 0.3mm 2B Pilot pencil lead, a timer, a ruler, a protractor, erasers, 3M Scotch Tape, acetate sheets and Flair 0.5mm multicoloured pen. A smartphone that was used to install the CephNinja app was an iPhone SE with A9 chipset, 64 GB memory, 2 GB RAM, and iOS software of 11.1.2 (Figure-1).

Fig-1: Research Armamentarium

Manual tracings were done on acetate sheets. A timer was turned on from the moment of landmark marking up to completion of Down's and Steiner's cephalometric analyses (Figure-2). The digital cephalograms were taken in a JPEG format and opened in the CephNinja app (Figure-3). The timer was again turned on at the time of landmark marking in the CephNinja app until the end of each analysis.

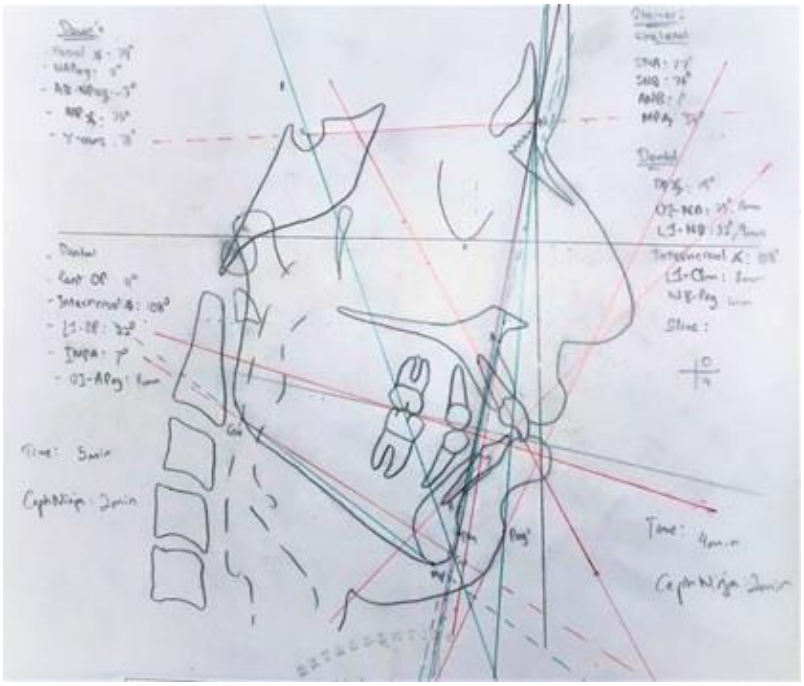

Fig-2: Conventional Method for Down's and Steiner's analyses

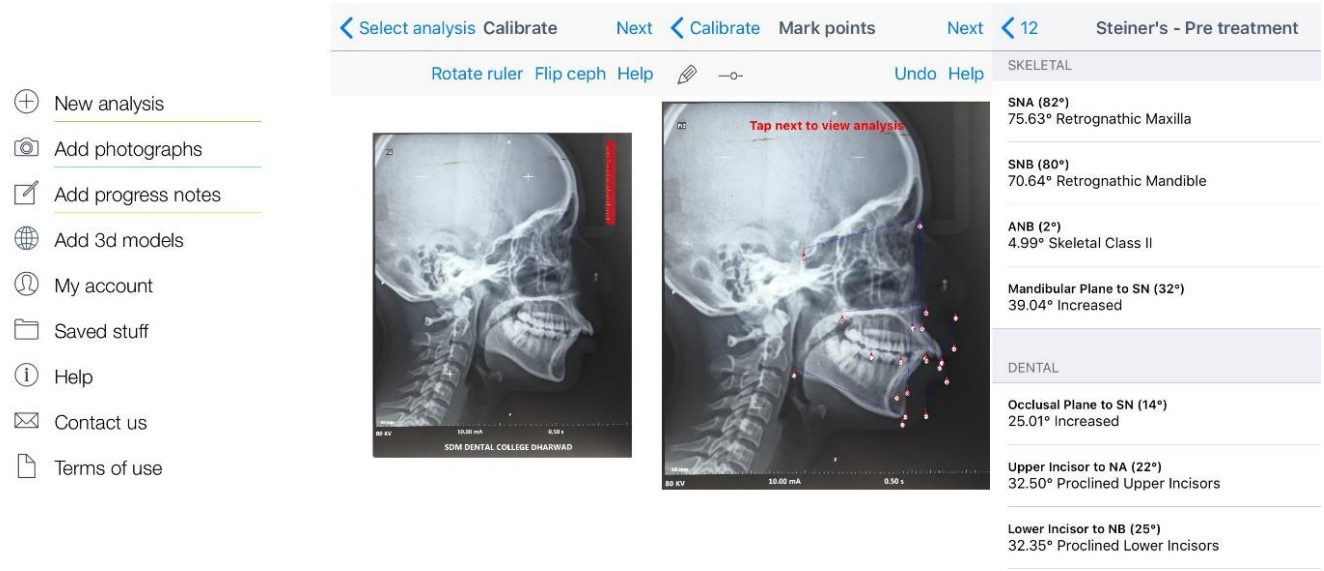

Fig-3: CephNinja App Interface

The values for each analysis done by conventional method and using the CephNinja app were tabulated. The time taken for each analysis using both methods were also inserted into the table. All the values were then statistically analysed. Before the statistical analysis, the normality assumption was tested using Kolmogorov Smirnov test. It showed that the normality assumption had been met except for Y-axis, interincisal angle and time scores in Down's analysis and interincisal angle, S-line to upper lip and time scores in Steiner's analysis. Therefore, a non-parametric test (Wilcoxon matched test) was applied for these values. For the other values, a parametric test (paired t test) was carried out.

RESULTS

Table-1 showed a comparison of values using manual and digital methods with parameters related to Down's analysis. Interincisal angle, lower incisor to occlusal plane angle and time scores showed significant differences between manual and digital methods ($p<0.05$). In other parameters, no differences between manual and digital methods were seen. The mean time taken for manual cephalometric analysis was 4.86 minutes while the digital method took only 2.18 minutes.

Table -1: Comparison of manual and digital methods with parameters related to Down's analysis by paired t / Wilcoxon matched pairs test

Variables	Methods	Mean	Std.Dv.	Mean Diff.	SD Diff.	Paired t/Z value	p-value
Facial Angle (N-Pog)	Manual	84.46	4.42				
	Digital	84.34	4.49	0.12	1.94	0.4354	0.6652
Angle of Convexity (NA-POG)	Manual	6.24	6.68				
	Digital	6.16	6.61	0.08	1.85	0.3243	0.7471
AB Plane Angle (AB-NPog)	Manual	-5.76	4.51				
	Digital	-5.77	4.04	0.01	2.14	0.0198	0.9842
Mandibular Plane Angle (Go-Me)	Manual	27.82	5.71				
	Digital	28.06	6.28	-0.24	2.17	-0.7743	0.4425
Y-axis (S-Gn)	Manual	60.64	5.90				
	Digital	72.86	82.88	-12.22	82.43	1.8534#	0.0638
Occlusal Plane D1	Manual	8.60	4.67				
	Digital	7.99	4.71	0.61	2.29	1.8945	0.0641
Interincisal Angle 1	Manual	113.88	9.76				
	Digital	108.58	22.13	5.30	21.43	2.8332#	0.0046*
Incisor Occlusal Plane (L1-OCC.PL.)	Manual	27.54	6.25				
	Digital	28.81	6.14	-1.27	3.12	-2.8836	0.0058*
IMPA (L1-MP)	Manual	8.46	6.91				
	Digital	8.70	6.86	-0.24	2.10	-0.8166	0.4181
U1-APog line	Manual	10.24	3.07				
	Digital	10.48	2.91	-0.24	1.10	-1.5738	0.1220
Time (Down's)	Manual	4.86	1.16				
	Digital	2.18	0.52	2.68	0.79	6.1540#	0.0001*

*p<0.05 = significant, # applied Wilcoxon matched pairs test

Table-2: Comparison of manual and digital method with parameters related to Steiner's analysis by paired t / Wilcoxon matched pairs test

Variables	Methods	Mean	Std.Dv.	Mean Diff.	SD Diff.	Paired t/Z	p-value
SNA	Manual	81.36	4.34				
	Digital	81.27	4.40	0.09	1.38	0.4570	0.6494
SNB	Manual	77.48	4.00				
	Digital	77.58	4.10	-0.10	1.15	-0.6080	0.5458
ANB	Manual	3.82	2.88				
	Digital	3.69	2.97	0.13	0.77	1.1860	0.2415
Mandibular Plane Angle (Go-Gn)	Manual	29.66	4.86				
	Digital	31.12	5.43	-1.46	1.70	-6.0670	0.0001*
Occlusal Plane S2 (1ST M - 1ST PM)	Manual	17.28	4.84				
	Digital	17.17	4.80	0.11	2.64	0.2880	0.7747
U1 Inclination (U1-NA)	Manual	32.42	8.00				
	Digital	32.90	7.21	-0.48	2.02	-1.6620	0.1029
U1 Position (U1-NA)	Manual	8.72	3.03				
	Digital	9.06	2.80	-0.34	0.94	-2.5770	0.0130*
L1 Inclination (L1-NB)	Manual	29.76	6.58				
	Digital	30.41	6.10	-0.65	2.32	-1.9870	0.0526
L1 Position (L1-NB)	Manual	7.26	2.65				
	Digital	8.18	4.37	-0.92	3.36	-1.9420	0.0579
Interincisal Angle 2	Manual	113.86	9.80				
	Digital	111.20	17.06	2.66	14.30	1.8679#	0.0618
S-line Upper Lip	Manual	2.56	1.92				
	Digital	4.80	18.32	-2.24	18.45	2.9394#	0.0033*
S-line Lower Lip	Manual	3.82	2.23				
	Digital	3.82	2.29	0.00	0.61	0.0510	0.9597
Time (Steiner's)	Manual	4.10	1.07				
	Digital	2.14	0.73	1.96	0.53	6.1540	0.0001*

*p<0.05, # applied Wilcoxon matched pairs test

Table-2 shows a comparison of manual and digital methods with parameters related to Steiner's analysis. The mandibular plane angle, linear measurement for upper incisor position, S-line to upper lip, and time scores showed significant differences between manual and digital methods ($p<0.05$). No differences were observed between manual and digital methods in the other parameters. The mean time taken for the analysis using CephNinja was 2.14 minutes whereas the manual method averaged out at 4.1 minutes.

In the final table, Table-3, which shows the correlation between manual and digital methods in both Down's and Steiner's analysis by Karl Pearson's method. It shows that a significant and positive relationship between the manual and digital methods in all parameters except Y-axis and S-line to upper lip. This means that the correlation between manual and digital methods are statistically significant.

Table-3: Correlation between manual and digital methods by Karl Pearson's correlation method

Variables	Methods	N	r-value	p-value
Facial Angle	Manual vs digital	50	0.9050	0.0001*
Angle Of Convexity (NA-Pog)	Manual vs digital	50	0.9610	0.0001*
AB Plane Angle (AB-NPog)	Manual vs digital	50	0.8810	0.0001*
Mandibular Plane Angle (Go-Me)	Manual vs digital	50	0.9390	0.0001*
Y-Axis (S-Gn)	Manual vs digital	50	0.1130	0.4340
Occlusal Plane D1	Manual vs digital	50	0.8810	0.0001*
Interincisal Angle 1	Manual vs digital	50	0.2920	0.0400*
Incisor Occlusal Plane Angle (L1-Occ.Pl.)	Manual vs digital	50	0.8730	0.0001*
IMPA (L1-MP)	Manual vs digital	50	0.9540	0.0001*
U1-APog	Manual vs digital	50	0.9340	0.0001*
Time (Down's)	Manual vs digital	50	0.8160	0.0001*
SNA	Manual vs digital	50	0.9500	0.0001*
SNB	Manual vs digital	50	0.9600	0.0001*
ANB	Manual vs digital	50	0.9660	0.0001*
Mandibular Plane Angle (Go-Gn)	Manual vs digital	50	0.9510	0.0001*
Occlusal Plane S2 (1ST M - 1ST PM)	Manual vs digital	50	0.8500	0.0001*
U1 Inclination (U1-NA)	Manual vs digital	50	0.9700	0.0001*
U1 Position (U1-NA)	Manual vs digital	50	0.9510	0.0001*
L1 Inclination (L1-NB)	Manual vs digital	50	0.9360	0.0001*
L1 Position (L1-NB)	Manual vs digital	50	0.6380	0.0001*
Interincisal Angle 2	Manual vs digital	50	0.5460	0.0001*
S-Line Upper Lip	Manual vs digital	50	-0.0140	0.9260
S-Line Lower Lip	Manual vs digital	50	0.9630	0.0001*
Time (Steiner's)	Manual vs digital	50	0.8950	0.0001*

*$p<0.05$ indicates the correlations between them are significant

DISCUSSION

Over the last decade, there has been a great rise of cephalometric apps in smartphones to aid orthodontists to carry out cephalometric analyses in their daily practice. These apps not only save the operator's time but is also easy to use and can be done within their palms. The increase in the number of apps has brought up a need to evaluate the reliability of these apps and compare them with the conventional manual cephalometric methods. Some studies have been done to compare the reliability cephalometric apps and the manual cephalometric method [9, 10].

A study by Erkan and his associates had stated the importance of standardisation in comparative studies like this study. The intra-examiner error is lesser than the inter-examiner error, thus, this study was standardised by having only one examiner for both manual cephalometric method and CephNinja app cephalometric method to reduce the possibility of errors. [11] In conventional methods, tracing errors can be contributed by the human eye's perceptive limits, pencil line thickness and mechanical errors caused by drawing lines between the cephalometric landmarks and during measurement with a protractor and ruler [12, 13]. However, the crucial source of tracing errors is from landmark identification inconsistencies which is seen in both the digitised and conventional method [14].

In this study, the comparison of interincisal angle and lower incisor to the occlusal plane angle in the Down's analysis showed differences between the manual and digital method in Down's analysis. This is down to the fact that angular dental measurements show greater differences than skeletal measurements as stated by a study by Chen and her associates in 2004. The variations in the measurements were due to the axis of the upper and lower incisors. Errors of these angular measurements were caused by the short distances between the landmark points for creating the tooth axis

of the incisors. Greater angular measurement errors were exhibited when two landmark points are closer [13]. Nagasaka also reported when the linear measurement error is at particular level, there is a theoretical relationship between a potential angular measurement error and interlandmark distance [15]. Blurred image due to superimposed structures may lead to difficulty in identifying landmarks such as the lower incisor apex [16].

The comparison of mandibular plane angle between the conventional method and its digital counterpart showed variations as well in Steiner's analysis. This is can be explained by the position of gnathion which is used to form a line with gonion to measure mandibular plane angle. The gonion shows variation in its' position in the vertical and horizontal axes. This may be due to the difficulty in delineating the landmark on the curved anatomical region [16]. The linear measurements in Steiner's analysis which are the upper incisor to NA line and upper lip to S-line showed variations in this study. The variations of these two variables may have resulted from the calibration or image distortion as seen by Celik and Aksakalli. They had found that linear parameters had greater differences than angular measurements [9, 17].

In general, the study had shown statistically significant values on correlation of manual and digital cephalometric methods except in the Y-axis and upper lip to the S-line values. These variables showed variations as a result of the difficulty of delineating the landmark of gonion for the Y-axis on a curved anatomical region and calibration or image distortion for the upper lip to S-line [9, 16, 17]. It can be said that the CephNinja app is as reliable as the conventional method and that the minimal variations are attributed by the operator's reproducibility of the landmarks and calibration of the cephalometric image in the app. In terms of the time that is required for an analysis to be carried out, it is no doubt that the digital cephalometric method, CephNinja app as for this study, reduces the time by half as compared to its conventional counterpart.

Conclusion

Modern day technology has rapidly advanced to what it is today and will only keep improving. This will have great impact on clinicians' practice and patients' treatment. The presence of cephalometric apps such as CephNinja and many more apps that will exist in the future will surely help clinicians in cephalometrics during treatment planning and reduce time consumption compared to conventional methods.

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