ACTA ODONTOLOGICA SCANDINAVICA, 2017
VOL. 75, NO. 8, 588–594
https://doi.org/10.1080/00016357.2017.1364420

Taylor & Francis
Taylor & Francis Group

ORIGINAL ARTICLE

Manual tracing versus smartphone application (app) tracing: a comparative study

Gülşilay Sayar and Delal Dara Kilinc

Department of Orthodontics, School of Dentistry, Istanbul Medipol University, Istanbul, Turkey

ABSTRACT

Objective: This study aimed to compare the results of conventional manual cephalometric tracing with those acquired with smartphone application cephalometric tracing.

Materials and methods: The cephalometric radiographs of 55 patients (25 females and 30 males) were traced via the manual and app methods and were subsequently examined with Steiner's analysis. Five skeletal measurements, five dental measurements and two soft tissue measurements were managed based on 21 landmarks. The durations of the performances of the two methods were also compared.

Results: SNA (Sella, Nasion, A point angle) and SNB (Sella, Nasion, B point angle) values for the manual method were statistically lower ($p < .001$) than those for the app method. The ANB value for the manual method was statistically lower than that of app method. L1–NB (°) and upper lip protrusion values for the manual method were statistically higher than those for the app method. Go-GN/SN, U1–NA (°) and U1–NA (mm) values for manual method were statistically lower than those for the app method. No differences between the two methods were found in the L1–NB (mm), occlusal plane to SN, interincisal angle or lower lip protrusion values.

Conclusions: Although statistically significant differences were found between the two methods, the cephalometric tracing proceeded faster with the app method than with the manual method.

ARTICLE HISTORY
Received 10 April 2017
Revised 4 July 2017
Accepted 31 July 2017

KEYWORDS
Cephalometry; smartphone application; tracing; mobile technologies

Introduction

Orthodontic radiography and cephalometric evaluation methods have exhibited much progress since Broadbent's standardization of the lateral cephalometric radiography technique in 1931 [1]. Cephalometric radiography is an essential method for case diagnosis, treatment planning, treatment prognostication, result acquisition and dental and craniofacial growth evaluations [2].

Cephalometric tracing is performed via manual and computerized approaches. The manual technique was the only method available for a long period of time [2]. The main disadvantages of manual tracing are that it is time-consuming, and it is possible for errors to originate in manual measurements that are performed with a protractor and a ruler [3]. The unprecedented evolution of computer technologies has paved the way for the use of digital programs in the production of cephalometric tracings. The Dolphin imaging software (Dolphin Imaging and Management Solutions, Chatsworth, CA), which was introduced in 1994, was the first digital innovation that was employed in the orthodontic field [2]. Since then, many other computer programs have been developed for digital cephalometric tracing.

Today, mobile technologies have undoubtedly become ubiquitous in daily life. As indicated in the 2014 Millward Brown study [4], which was conducted in 30 countries around the world, mobile devices account for 47% of the total daily screen time. Moreover, among these devices, 35% are smartphones, the users of which spend 147 minutes per day interacting over their devices, making smartphones the leading largest screen medium in the world. In addition to being powerful handheld computers with complete mobile operating systems, smartphones serve as personal data assistants, cameras, video recorders, media players, global positioning system receivers, game stations and access points for the collection of games, resources, broadband access and communication tools [5].

Promising, exciting and trendy smartphone technologies have exerted non-negligible effects on the medical field. In daily medical practice, smartphones play important roles that range from patient monitoring and diagnostics to effective medical education and communication [6]. Given that a smartphone is an easy and fast tool that can be used to facilitate clinical practice [5,7–9], the associated technologies are being adopted and embraced by clinicians, medical students, patients and health care organizations [5]. An HIMSS report [10] indicated that in 2014, 83% of physicians used smartphones for work-related purposes, and the device most preferred by these practitioners was the iPhone, followed by smartphones with the Android and Blackberry operating systems [11]. Each of the popular operating systems, e.g. iPhone iOS, Android and Blackberry, is accessible through an

CONTACT Gülşilay Sayar gsayar@medipol.edu.tr Department of Orthodontics, School of Dentistry, Istanbul Medipol University, Atatürk Bulvarı No. 27, 34083 Unkapani – Fatih, Istanbul, Turkey

application distribution store from which users can select and download applications in which they are interested [11].

A smartphone application (app) is a small-scale specialized software program that can be downloaded onto a mobile device [12]. Such smart mobile technologies enhance the possibilities of dental practice [13], and their consistent development has reconfigured dental care to involve the use of mobile phone apps [8,14,15]. More than any other dental specialization, orthodontics has used computer technologies in diagnosis, treatment planning and data storage [2]. Across the entire dental field, orthodontics has been a leading specialization area [16].

In this study, we aimed to compare linear and angular measurements obtained with smartphone app tracing (app method) and manual tracing (manual method) methods. An additional goal of this study was to evaluate the reliability of the smartphone-based approach as a cephalometric tracing method for orthodontics. The null hypothesis was that the results of tracings performed using a smartphone app would not be significantly different from those obtained from tracings performed by hand, but the app method would require statistically less time to perform.

Materials and methods

The digital lateral cephalometric radiographs of 55 orthodontic patients (25 females and 30 males) with a mean age of 13.10 ± 2.20 and permanent dentition were randomly selected from the database of the Department of Orthodontics at the Faculty of Dentistry of Istanbul Medipol University. The Research Ethics Committee of Istanbul Medipol University reviewed and approved this study under Protocol Number 10840098-604.01.01-E.9265. The lateral radiographs were obtained at the same radiological clinic by the same technician. As the cephalometric exposure was performed, the patient's head was immobilized using a cephalostat guided by a Frankfort horizontal plane that was positioned parallel to the ground and perpendicular to the mid-sagittal plane.

Both the manual and app tracings were performed by a single examiner (XXX) to minimize the variability of the measurements. This examiner had a clinical experience of 9 years as an orthodontist.

Manual cephalometric tracing method

To avoid examiner fatigue, the manual tracings of the 55 lateral cephalograms were performed over five days, and 11 lateral radiographs were collected each day. Transparent tracing paper (Straight Line Acetate Tracing Paper, G&H, Franklin, TN) with dimensions of 8×10 inches and a thickness of 0.003 mm was placed on the hard copies of lateral cephalograms. Calibration was done before printing the images and the tracing was subsequently performed using a mechanical pencil with a 0.3-mm lead tip.

Steiner's analysis was adopted for the cephalometric analysis because of the frequent use of this technique in our clinics and its availability for cephalometric analysis in the smartphone's selection menu. The analysis involved five skeletal measurements, five dental measurements and two soft tissue measurements. The cephalogram was labelled with 21 landmarks, namely, Point S (sella), Point N (nasion), Point A (A), Point B (B), Gonion (Go), Gnathion (Gn), Upper Incisor Edge (U1i), Upper Incisor Root Apex (U1r), Lower Incisor Incisal Edge (L1i), Lower Incisor Root Apex (L1r), Upper Incisor Crown Facial Surface (U1f), Lower Incisor Crown Facial Surface (L1f), Posterior Nasal Spine (PNS), Anterior Nasal Spine (ANS), Occlusal Contact Point in the First Molar Region (OCm), Occlusal Contact Point in the Premolar Region (OCp), Pogonion (Pog), Columella of the Nose (i.e. the mid-point between the subnasal point and the nose tip), Upper Lip (UL), Lower Lip (LL) and Soft Tissue Pogonion (Pog').

After the landmarks were traced, the lines and planes to be used in the analysis were obtained (Figure 1). The angular and linear hard and soft tissue parameters used in the study are listed below.

Angular parameters:

- SNA: angle between sella nasion and A point.
- SNB: angle between sella nasion and B point.
- ANB: difference between SNA and SNB.
- U1–NA (°): upper incisor to NA line (the angle between the axis of upper incisor and NA line).
- L1–NB (°): lower incisor to NB line (the angle between the axis of lower incisor and NB line).
- Go-GN/SN: Steiner's mandibular plane angle.
- Occlusal plane to SN: angle between the sella nasion and the occlusal plane.
- Interincisal angle: The angle between the axis of upper incisor and the axis of lower incisor.

Linear parameters:

- U1–NA (mm): the distance between labial surface upper incisor to NA line.
- L1–NB (mm): the distance between labial surface lower incisor to NB line.
- Upper lip protrusion: upper lip to Steiner's S line.
- Lower lip protrusion: lower lip to Steiner's S line.

The angular measurements were performed with a cephalometric protractor, and the linear measurements were performed to the nearest 0.5 mm using a millimetre ruler. The obtained data were then tabulated for statistical analysis. The time required for each lateral cephalogram was registered using a chronometer, and the time results were tabulated for statistical analysis.

Smartphone app cephalometric tracing method

In the first stage, the examiner performed 10 sequential random tracings using the application until the researcher mastered the method. After calibration, 55 tracings were performed. To avoid examiner fatigue, app tracings of the 55 lateral cephalograms were performed over five days, and 11 lateral radiographs were collected each day. A smartphone

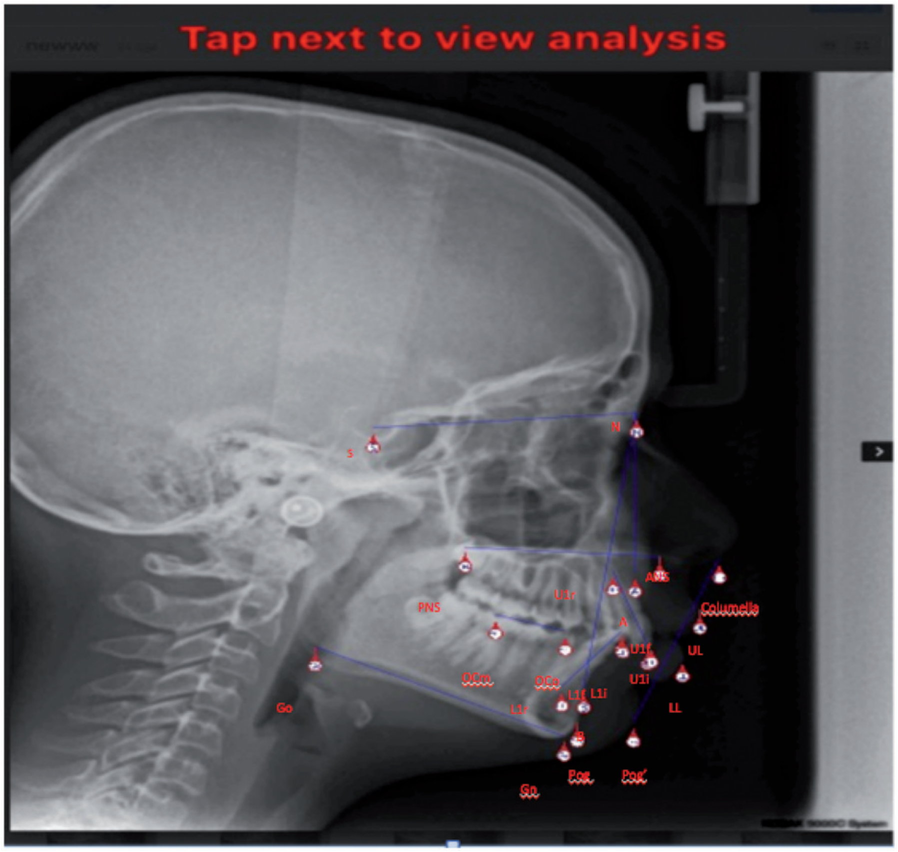

Figure 1. Cephalometric landmarks.

(iPhone 5 with IOS 9.3.2) was used to evaluate the cephalograms. The terms ‘cephalometric’, ‘cephalometry’, ‘cephalogram’, ‘orthodontic tracing’ and ‘cephalometric tracing’ were entered into the iPhone’s search facility to obtain a list of apps that enable cephalometric tracing. The search results returned only the CephNinja 3.10 app (Individual Trademark Owner: Rohit Madan), and this app was then downloaded onto the smartphone after the fees were paid. The digital images of the 55 lateral radiographs were sent to the phone via an e-mail from the main server on which the data were stored. The images were downloaded and saved in the photo gallery of the phone, and no changes were made to the image quality. All the images displayed an identification number as they were downloaded.

After the cephalogram images were saved in the photo gallery, CephNinja 3.10 was applied. Clicking on the new analysis option in the menu toolbar allowed for the selection of the preferred images, which were then uploaded from the photo gallery. After an image was chosen from the photo gallery, it was transferred into a crop box for resizing into useful scales. Tapping the ‘next’ option resulted in the display of a menu for the selection of the cephalometric analysis type. This menu contains the following options: Steiner’s, Wits appraisal, Burstone’s/COGS, Down’s, Jarabak’s, McNamara’s and Tweed’s analyses, and a composite analysis method (which was created by choosing a variety of analysis approaches). As previously stated, we opted for Steiner’s analysis (Figure 2). Calibration was performed, and tracing subsequently commenced (Figure 3). Double tapping enabled the marking of the landmarks used for the analysis on sequential images as prompted by the app. At this stage, the examiner zoomed in on the image via a pinching gesture on the dropped pins, which effectively and accurately marked the landmarks.

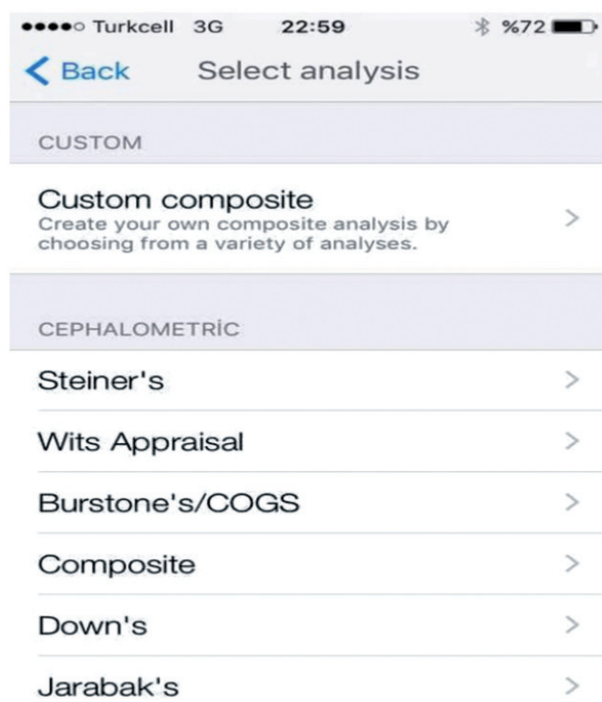

Figure 2. Analysis selection tool.

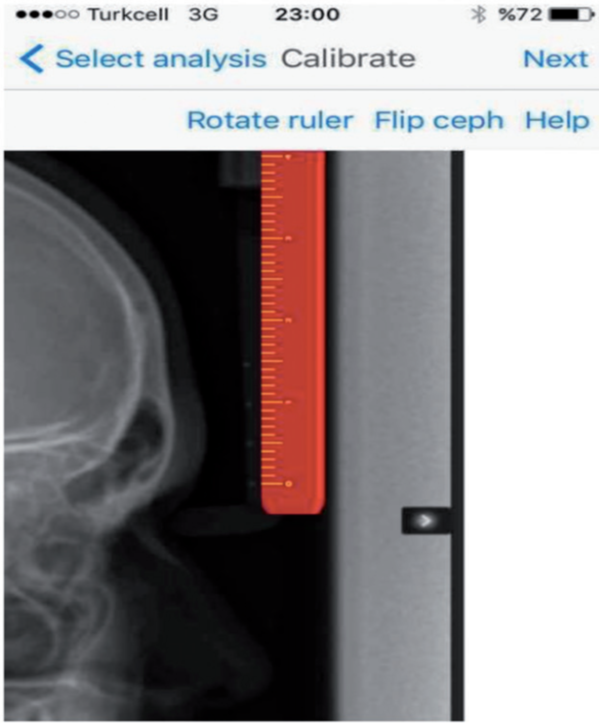

Figure 3. Calibration ruler.

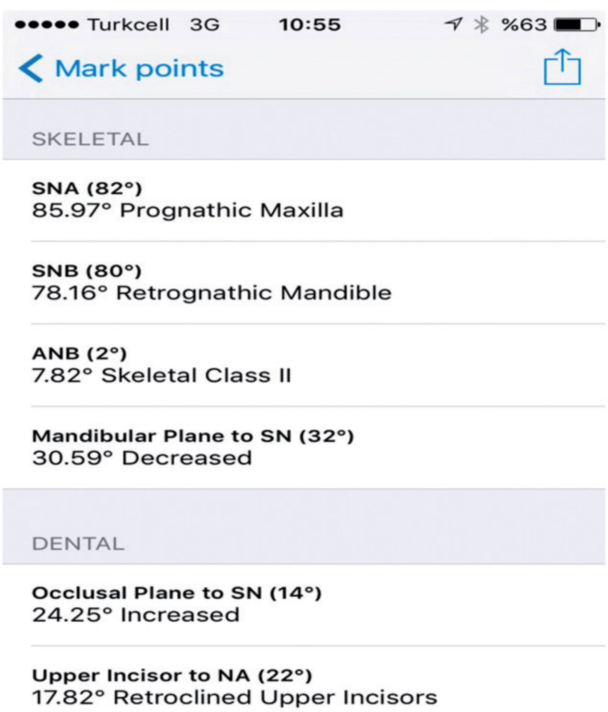

Figure 4. Screenshot of app method results.

Zooming in allowed the examiner to easily hold and drag the pins to exact positions.

Tapping on the 'next' option saved the obtained linear and angular results of the app tracing to a folder (Figure 4). The results were then also tabulated individually by the examiner for statistical analysis. The time required for each lateral cephalogram was registered using a chronometer, and the time results were tabulated for statistical analysis.

Statistical analysis

The significant differences between the durations required for the tracings and the angular and linear measurements derived with the manual and app methods were evaluated using statistical software (IBM SPSS V23.0, IBM Corp., Armonk, NY). Shapiro–Wilk's test was conducted to examine the normalities of the data. Normally distributed data were then evaluated with the paired samples *t* tests. After 20 days, the intra-examiner error was assessed based on 10 new randomly selected tracings (five manual and five digital). The method error was calculated and was found as 0.92 by using Houston's formula [17]. The results were evaluated with the 95% confidence intervals (CIs), and the significance level was set at $p < .05$. The reliabilities of the measurements were evaluated by performing interclass correlation coefficient analyses with the 95% CIs.

Results

The mean values and the standard deviations for the normally distributed data are presented in Table 1.

The performance duration of the manual method was found to be significantly higher ($p < .001$) than that of the app method.

The SNA and SNB values for the manual method were found to be significantly lower ($p < .001$) than those for the app method.

The ANB values for the manual method were statistically lower than that of app method. The L1–NB (°) values for the manual method were statistically greater than those for the app method.

The Go-GN/SN, U1–NA (°) and U1–NA (mm) and upper lip protrusion values for the manual method were statistically lower than those for the app method.

There were no differences in the L1–NB (mm), occlusal plane to SN, interincisal angle or lower lip protrusion values between the manual and app methods.

The ICC values for all items ranged between 0.9100 and 0.9726 (Table 2).

Discussion

This study aimed to compare the performance durations and the tracing results between the manual and app methods. Prabhakar et al. [18] explained the dependence of digital radiography on computers and underlined the necessity for additional hardware and software. Manual tracing requires equipment that includes a ruler, protractor, view box and tracing paper, whereas smartphone apps require none of this equipment. Correspondingly, the use of smartphones by physicians is increasing rapidly day-by-day [5,6,11,14,19,20].

Mobile applications can take dentistry a step further [15]. Numerous smartphone apps that are related to orthodontics

Table 1. Linear and angular parameters used in the study and their values.

Parameters	App cephalometric tracing method values	Manual cephalometric tracing method values	Difference between app tracing and manual tracing	p
Performing duration (minutes)	2.460 ± 0.200	4.3200 ± 0.1300	−1.861 ± 0.233	$p < .001$***
SNA (°)	82.500 ± 4.000	81.300 ± 3.700	1.263 ± 1.505	$p < .001$***
SNB (°)	78.600 ± 4.200	77.600 ± 4.000	0.965 ± 1.42	$p < .001$***
ANB (°)	3.910 ± 2.600	3.700 ± 2.390	0.298 ± 0.841	.011*
Occlusal plane to SN (°)	16.500 ± 6.200	16.400 ± 5.500	0.123 ± 2.233	.683 NS
GoGn to SN (°)	32.600 ± 6.800	31.900 ± 6.500	0.72 ± 1.567	.001**
U1–NA (mm)	2.270 ± 1.670	2.070 ± 1.720	0.2 ± 0.574	.012*
L1–NB (mm)	2.520 ± 1.130	2.470 ± 1.090	0.045 ± 0.473	.479 NS
Interincisal (°)	126.000 ± 11.000	126.300 ± 10.200	−0.317 ± 3.754	.534 NS
U1–NA (°)	25.400 ± 8.400	24.700 ± 8.100	0.746 ± 2.676	.043*
L1–NB (°)	25.000 ± 7.100	25.900 ± 6.300	−0.844 ± 2.242	.007**
Upper lip protrusion (mm)	−1.039 ± 1.084	−0.870 ± 1.038	−0.169 ± 0.361	.001**
Lower lip protrusion (mm)	−0.261 ± 1.273	−0.166 ± 1.167	−0.095 ± 0.407	.088 NS

*$p < 0.05$
**$p < 0.01$
***$p < 0.001$

Table 2. Intraclass correlation coefficient values of the parameters between the app and manual methods with 95% confidence interval.

	ICC	95% CI of ICC
SNA (°)	0.9243	0.8737–0.9551
SNB (°)	0.9398	0.8990–0.9644
ANB (°)	0.9442	0.9061–0.9670
Occlusal plane to SN (°)	0.9280	0.8796–0.9573
GoGn to SN (°)	0.9726	0.9535–0.9839
U1–NA (mm)	0.9424	0.9033–0.9660
L1–NB (mm)	0.9100	0.8506–0.9465
Interincisal (°)	0.9373	0.8949–0.9630
U1–NA (°)	0.9469	0.9106–0.9687
L1–NB (°)	0.9446	0.9069–0.9673
Upper lip protrusion (mm)	0.9421	0.9028–0.9658
Lower lip protrusion (mm)	0.9443	0.9064–0.9671

have been used by orthodontic clinicians and patients [12,21]. Mamillapalli et al. [8] and Pavan et al. [9] used different smartphone apps for orthodontic evaluations that involved model analysis and the determination of cervical vertebral maturation. In the present study, we used CephNinja 3.10. As the Android version of this app is insufficiently effective and requires further development, an Apple device was used in this work.

For a very long period of time, the manual tracing method was the only method available for cephalometric analyses [2]. The problem with this traditional approach is that it is time consuming and prone to errors due to the limitations of the human eye [3]. Additionally, the smallest scale on a conventional instrument is the millimetre for linear measurements and is the degree value for angular measurements, which limits the accuracy of such tools [3]. Chen et al. [3] also argued that because manual tracing is performed with a ruler and a protractor with a lead pencil, the dotted points and lines are characterized by widths that can affect the accuracy of the results. These factors may explain the differences between the measurement results obtained in our study. Rudolph et al. [22] discussed the repeatability and accuracy of manual tracings and identified some factors that cause measurement errors or variations in image identification and landmark acquisition. Despite the insights derived from previous works, comparisons of app tracing with any other methods are not found in the literature. Therefore, the only data related to non-manual tracings that were used in the present research were those from the digitized and computerized tracing methods.

The cephalograms used in this study were digital cephalograms. As the characteristics of digital cephalograms are superior to those of conventional radiographs, digital cephalograms are highly valued sources of data in orthodontic clinics [22]. The major advantage of digital radiography is the remarkable reduction in patient radiation exposure. This technique also enables the acquisition of soft copies of the data [18].

Chen et al. [3] noted that computer-aided cephalometric analysis enables faster data identification and evaluation compared with traditional methods. Furthermore, such analysis enables the operator to alter the visual appearance of the images through the manipulation of brightness and contrast and allows for zooming in, which facilitates accurate and easy landmark identification [3,18].

Similar to our study, Prabhakar et al. [18] compared two different computerized methods and a manual tracing method. These authors found no significant differences in the results, and these findings contrast with our outcomes. Specifically, in our work, only the following measurements exhibited no differences between the methods: L1–NB (mm), occlusal plane to SN, interincisal angle and lower lip protrusion. Paixão et al. [2] highlighted the difficulty of tracing the maxillary and mandibular dental structures and found significant differences in the measurements of maxillary and mandibular incisors. These results match the findings obtained in the current research; that is, the two tracing methods significantly differed in terms of the majority of the dental structural measurements. Chen et al. [3] investigated the durations required for tracing among three clinicians with different experience levels and found statistically significant differences between the groups. These authors mentioned that tracing via the use of a computerized tracing method reduced the clinical time required to perform cephalometric evaluation, i.e. this time was significantly different from that associated with traditional manual tracing with a ruler and a protractor. Moreover, the use of a computerized method can minimize the error margin that is normally encountered with the manual tracing technique [3]. In the present study, the tracing durations associated with the app and manual methods were compared for each lateral radiograph. Our time results are consistent with those of Chen et al. [3]; specifically, the app method was substantially faster than the conventional manual tracing method.

In contrast to our work, Chen et al. [3] and Paixão et al. [2] found no significant differences in any of measurements acquired with digital cephalometric tracing and manual cephalometric tracing. These authors argued that the computerized method resulted in a lower range of error than the traditional method and thus increased measurement reliability [2]. In contrast, Forsyth et al. [23] revealed that errors in the angular and linear measurements acquired from digital images are greater than those that occur with traditional manual tracing. However, after comparing several cephalometric tracing methods, other researchers [2,3,24] have confirmed the reliability of digital tracing in orthodontic practice. However, despite the clinical acceptance, some researchers have claimed the existence of significant differences between results obtained with these methods [2,3]. Our findings are consistent with this claim.

This study revealed that most of the measurements in app tracing method were found higher than that of the manual tracing method. Only the interincisal angle and the L1–NB (°) were found lower in app tracing method. These measurements which are related to dental axis of the lower incisors, can be originated from the sensitivity of app tracing screen. During the detection of the dental axis of the lower incisors, extra zoom in was performed in app tracing method. We think that this situation was the reason of the difference in these findings.

In this study, internal consistency defines the reliability of examination of each parameter with different methods. We could not compare our results with another research, because of the lack of similar studies evaluating ICC parameters in the literature. It was reported that ICC values higher than 0.80 defines a strong reliability [25]. In the light of this information in our study all of the ICC values can be considered as excellent.

Few studies have been devoted to smartphone app usage in orthodontics. Nevertheless, apps are predicted to play much greater roles in the diagnosis, treatment planning and prognostication of orthodontic patients in the future.

Conclusions

The zoom-in functionality of smartphones enables the magnification of a specific area, and thus facilitates detailed studies by an examiner. In the present work, the tracing results revealed significant differences in the majority of the measurements. There were no differences in the L1–NB (mm), occlusal plane to SN, interincisal angle and lower lip protrusion values between the two methods.

Smartphone use allows for a very fast tracing method, and a substantial difference in the analysis durations was found between the two compared methods.

Although statistically significant differences between the measurements acquired with the two methods were found, we believe that there are no 'clinically' significant differences between the methods.

Rapidly developing mobile technology will be a potential game changer in the future of medical and dental clinical applications.

Disclosure statement

The authors declare that they have no potential conflict of interest.

References

[1] Broadbent BH. A new X-ray technique and its application to orthodontia. Angle Orthod. 1982;51:93–114.
[2] Paixão MB, Sobral MC, Vogel CJ, et al. Comparative study between manual and digital cephalometric tracing using Dolphin Imaging software with lateral radiographs. Dental Press J Orthod. 2010;15:123–130.
[3] Chen SK, Chen YJ, Yao CC, et al. Enhanced speed and precision of measurement in a computer-assisted digital cephalometric analysis system. Angle Orthod. 2004;74:501–507.
[4] Millward Brown Study, AdReaction. Marketing in a multiscreen world; [Internet]. 2014. Available from: http://www.millwardbrown.com/AdReaction/2014/#/
[5] Mohan AT, Branford OA. iGuide to plastic surgery: iPhone apps, the plastic surgeon, and the health care environment. Aesthet Surg J. 2012;32:653–658.
[6] Ozdalga E, Ozdalga A, Ahuja N. The smartphone in medicine: a review of current and potential use among physicians and students. J Med Internet Res. 2012;14:e128.
[7] Adams BW. Automation and apps for clinical dental biomechanics. Cranio. 2016;34:343–347.
[8] Mamillapalli PK, Sesham VM, Neela PK, et al. A smartphone app for identifying cervical vertebral maturation stages. J Clin Orthod. 2015;49:582–585.
[9] Pavan KM, Praveen KN, Murthy S. Model analysis on a smartphone. J Clin Orthod. 2012;46:356–358.
[10] HIMMS (Health Information Management Systems Society) Analytics. Available from: http://www.himss.org/3rd-annual-himss-analytics-mobile-survey-full-results?ItemNumber =41967 [cited 2017 Jul 4]. Available from: https://connectedworld.com/wp-content/uploads/2014/07/Whitepaper_HIMSSAnalytics_3rdAnnualHIMSSAnalyticsMobileSurvey.pdf.
[11] Franko OI, Tirrell TF. Smartphone app use among medical providers in ACGME training programs. J Med Syst. 2012;36:3135–3139.
[12] Singh P. Orthodontic apps for smartphones. J Orthod. 2013;40:249–255.
[13] Plangger K, Bredican J, Mills AJ, et al. Smart dental practice: capitalising on smart mobile technology. Br Dent J. 2015;219:135–138.
[14] Khatoon B, Hill KB, Walmsley AD. Can we learn, teach and practise dentistry anywhere, anytime? Br Dent J. 2013;215:345–347.
[15] Stein CD, Xiao X, Levine S, et al. A prototype mobile application for triaging dental emergencies. J Am Dent Assoc. 2016;147:782–791.
[16] Wang CH, Randazzo L. Evolution of imaging and management systems in orthodontics. Am J Orthod Dentofacial Orthop. 2016;149:798–805.
[17] Houston WJB. The analysis of errors in orthodontic measurements. Am J Orthod. 1983;83:382–389.
[18] Prabhakar R, Rajakumar P, Karthikeyan MK, et al. A hard tissue cephalometric comparative study between hand tracing and computerized tracing. J Pharm Bioall Sci. 2014;6(Suppl 1):S101–S106.
[19] Choi JS, Yi B, Park JH, et al. The uses of the smartphone for doctors: an empirical study from Samsung Medical Center. Healthc Inform Res. 2011;17:131–138.

[20] Tran K, Morra D, Lo V, et al. The use of smartphones on General Internal Medicine wards: a mixed methods study. Appl Clin Inform. 2014;5:814–823.
[21] Baheti MJ, Toshniwal N. Orthodontic apps at fingertips. Prog Orthod. 2014;15:36.
[22] Rudolph DJ, Sinclair PM, Coggins JM. Automatic computerized radiographic identification of cephalometric landmarks. Am J Orthod Dentofacial Orthop. 1998;113: 173–179.
[23] Forsyth DB, Shaw WC, Richmond S. Digital imaging of cephalometric radiography. Part 1: advantages and limitations of digital imaging. Angle Orthod. 1996;66:37–42.
[24] Tanikawa C, Yagi M, Takada K. Automated cephalometry: system performance reliability using landmark-dependent criteria. Angle Orthod. 2009;79:1037–1046.
[25] Bland JM, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. Lancet. 1986;1:307–310.