International Journal of Applied Dental Sciences

ISSN Print: 2394-7489
ISSN Online: 2394-7497
IJADS 2018; 4(3): 314-322

www.oraljournal.com
Received: 24-05-2018
Accepted: 26-06-2018

Reem Sami Alwakeel
Senior Dental Student, King Saud Bin Abdulaziz for Health Sciences, College of Dentistry, Riyadh, Saudi Arabia

Mohammed Awawdeh
Assistant Professors, Department Orthodontic, King Saud Bin Abdulaziz for Health Sciences, College of Dentistry, Riyadh, Saudi Arabia

Deena Mahmoud Barakah
DDS, Registrar Health Informatics, Dental Clinic Department, King Saud Medical City, Ministry of Health, Riyadh, Saudi Arabia

Correspondence
Reem Sami Alwakeel
Senior Dental Student, King Saud Bin Abdulaziz for Health Sciences, College of Dentistry, Riyadh, Saudi Arabia

Measurement accuracy of space analysis by smart phone applications for orthodontic purposes: a comparison study with conventional plaster dental models

Reem Sami Alwakeel, Mohammed Awawdeh and Deena Mahmoud Barakah

Abstract

Introduction: Our objective is to assess how accurate and valid the measurement estimates made by smartphone apps programs are on photos taken by smartphone digital camera when compared to those obtained from plaster models.

Method: A set of several alginate impressions was taken from siblings with different types of occlusion. A written consent form were taken from all of the participants. Each impression was made into a plaster cast and photos were taken by smartphone digital camera. Direct photos were also taken of siblings' dentition. Different mobile apps software programs that are currently available for both Iphone and Android OS smartphones were then used to measure the photos of the tooth widths at their greatest mesiodistal dimension and arch length. Tooth and arch widths were again physically measured on the plaster models with a divider and a millimeter ruler.

Result: When comparing measurements estimated from the smartphone photos, obtained through different measuring smartphone apps, with those of the conventional plaster dental study models, we found that there was no significant difference in space analysis between them. For the photos taken directly from the patients' mouths, there was a slight significant difference (0.1mm) in the spacing and crowding estimates.

Conclusion: The measurement accuracy obtained through smartphone apps and photos for dental space analysis evaluation is clinically acceptable. Their measurement estimates are virtually identical to their counterparts in the traditional plaster study models. Overall, smartphone apps digital photo measurements are as reliable as traditional plaster models measurement in accuracy.

Keywords: Dental casts, space analysis, digital study models, smartphone dental apps; digital orthodontic measurement

1. Introduction

It is well established that physicians and dentists are heavy users of IT-based applications and technologies in their daily clinical activities [1]. Various research studies have found that mobile health applications through the use of smartphones and wireless devices are rapidly spreading, and contribute to improvements in patient outcome expectations, health research advancement and health care services [2, 3]. Currently, more orthodontics and practitioners are serving their specialty by using smartphone technologies. Many dental practitioners now take advantage of advanced mobile apps that make managing dental tasks more efficient. This is due to the existence of numerous software applications that carry extensive utility and aggregation of multiple programs and technologies in a single device. As a result, smartphones are utilized in dental practice in ways never before thought possible, for lowering administrative costs, increasing dental work efficiency, reducing medical errors, educating patients, and facilitating patient-dentist interaction [4].

Considering the above, our research is related to the question: Can we take advantage of smartphone digital photos and the many mobile measurement apps now available in orthodontic practice?

One crucial need of the orthodontic dentist is dental space analysis for determining the amount of spacing or crowding in patients. This analysis aids the treatment process and the progress of the treatment. Traditionally, space analysis is done by measuring the mesiodistal length of each tooth mesial to the first molar tooth, referred to as "the space required". This is followed by measuring the arch length, referred to as "space available". Finally, space analysis is the result of space available subtracted by space required [5].

To evaluate space analysis, many computerized tools have been used in recent years. Computer-aided digitalization based on photos, photocopies, and holograms has been performed and reported in many articles [6]. In addition, certain specialized software, such as OrthoCad7.6 for orthodontic analysis has also been developed. Schirmer and Wiltshire have conducted space analysis by comparing manual measurements obtained from traditional plaster casts with a digitalized model of the cast taken by photocopier. The result of their study concluded that the plaster model was the most accurate and reliable source for the measurement[9]. Kumar *et al*. compared tooth-width measurements and calculated anterior and overall Bolton ratios on the digital models (CBCT, CAD/CAM) with those of plaster models. They concluded that digital models of CAD/CAM and CBCT did not differ significantly from those of the plaster models [10]. Bell *et al*. performed a comparative assessment between direct measurements of dental study models and measurements of computer generated 3D images. They found that the average difference between measurements of dental casts and 3D images was within the range of operator error (0.10–0.48 mm) and was not statistically significant (P 0.05) [11]. According to Leifert *et al*., there was a slight statistically significant difference (0.4 mm) in the maxillary cast when they compared the plaster cast with a 3-dimensional virtual orthodontic model, generated by computer software [1, 2]. Following this trend of using digital tools and devices for evaluating dental measurements, we conducted this study, at the College of Dentistry at King Saud bin Abdul-Aziz University for Health Science, in Riyadh, Saudi Arabia. The aim of our study is to assess the accuracy and reliability of space measurements obtained from photos taken by smartphone camera using apps programs in comparison to those obtained from plaster models. The introduction of measuring apps programs for photos taken by smartphone camera could offer a new efficient alternative to the time-consuming method of physically measuring a plaster model using specific types of instruments [2]. To the best of our knowledge, no dental space analysis has yet been performed by measurement apps programs using smartphone digital camera photos. We expect that using these types of smartphone apps programs for serving orthodontic purposes, will facilitate undertaking this tedious task and will be seen as a significant innovation in the field of orthodontic dentistry.

2. Material and methods

Impressions were randomly taken from three siblings with different types of occlusion The reason for choosing siblings is to ensure that patients have similar size, anatomic variations and morphology of the teeth. A written consent form were taken from all of the participants. Two sets were taken from each of the three siblings. For the first set, the patient had already completed orthodontic camouflage treatment and extraction of the first upper premolars with no spacing or crowding, but there was relapse and crowding in the lower anterior region. Figure 1 shows the plaster cast impressions for this set. In the second set, the patient had orthodontic treatment. Also, the patient had no spacing or crowding, although two deciduous2nd primary molars were retained due to congenitally missing permanent 2nd premolars. Figure 2 shows the plaster cast impressions for this set. Regarding the third set, the patient did not have any orthodontic treatment, and had spacing in the upper and lower casts. Figure 3 shows the plaster cast impressions for the upper case of this set. Measuring space analysis in the plaster model was performed by first measuring the “space required”, using a divider and a ruler to measure the mesiodistal length for each tooth mesial to the first molar teeth. This was followed by measuring “space available”, of the arch length, which constitutes four areas (2nd premolar to canine, lateral to central, central to lateral, canine to 2nd premolar). The final space analysis was the result of “space available” subtracted by “space required”. The space analysis measurements obtained from the conventional plaster casts for the three study sets are recorded in Figure 4. Subsequently, different measurement program apps for both IPhone and Android OS smartphones were downloaded. For the IPhone, the “Measurement Tool” was selected, and for the Android OS smartphone, the choice was the “Photo Ruler” app. All measuring apps provide help documents for how to use the program, capture the image and perform the measurement. All measuring apps also include a fixed measuring object animation that appears next to the object that is to be measured. To calibrate the app measurement, a physical external ruler and a credit card were used for comparison with the app’s virtual ruler and credit cards. Depending on the app program, a dimension pointer showing the measured values of the desired object may appear, as shown in Figs 5 and 6. From these values, we obtained the space required and space available, shown in Tables 1 and Table 2. A summary of app measurements is shown in Table 3. Furthermore, to check for accuracy of calibration, we used these apps programs to obtain space analysis measurements directly from photos of the patient’s mouth. All the measurements were recorded in centimeter units and then rounded to the nearest 0.1 mm.

Figure 1. Set 1 plaster cast impression

Figure 2. Set 2 plaster cast impression

Figure 3 shows the plaster cast impressions for this set.

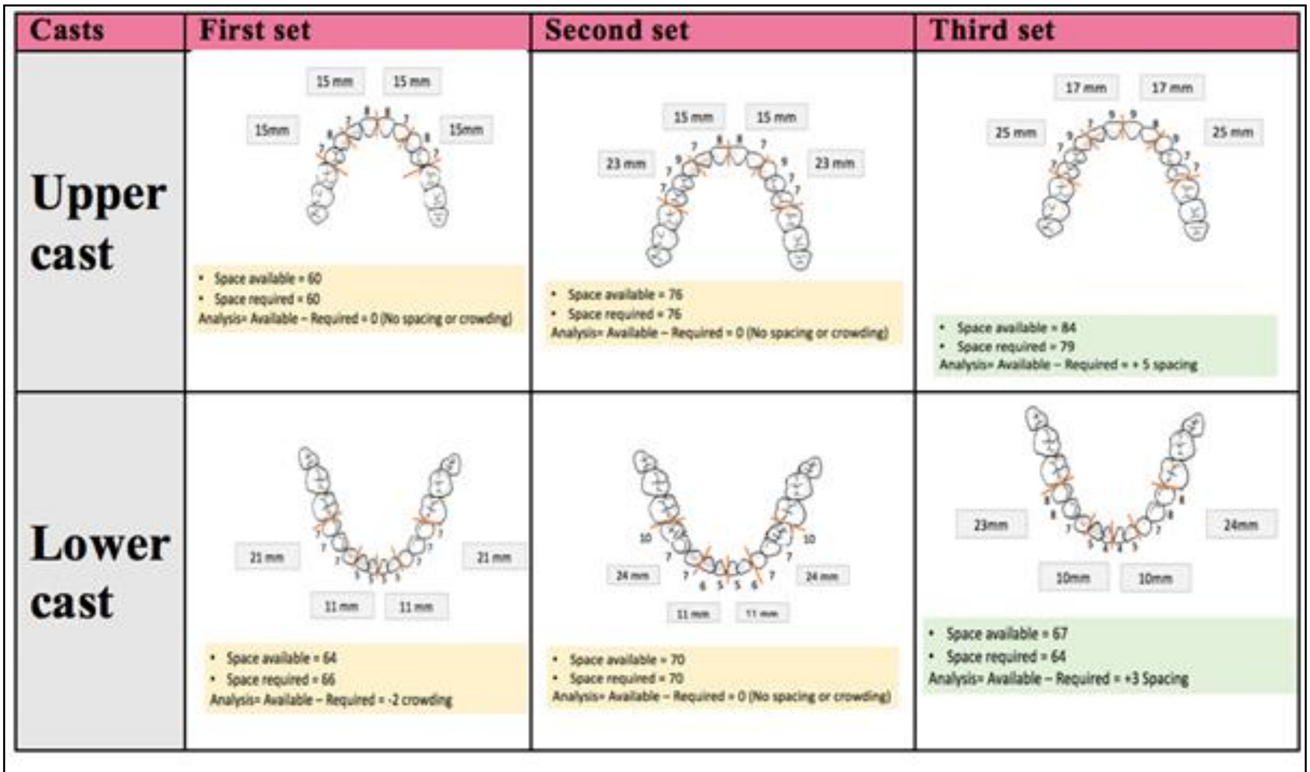

Figure 4 Summary of space required and space available results

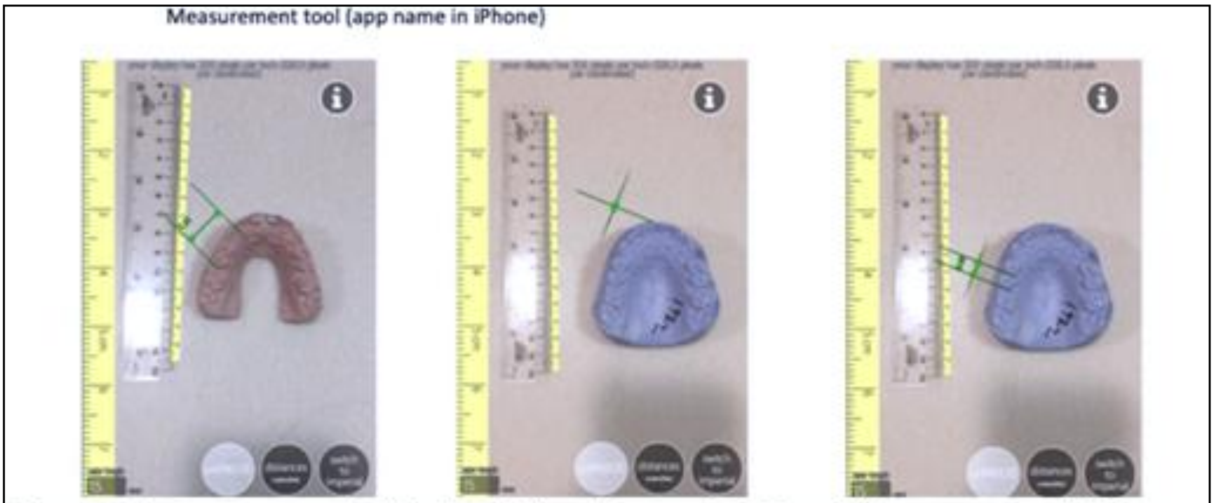

Figure 5. Measurement and calibration of dental Space using IPhone "Measurement tool "APP.

Figure 6. Measurement and calibration of dental Space analysis using Android "Photo Ruler "APP.

IPHONE Upper case ``First Set	Set distances		Teeth space		difference
	22 19 21 20		10 11 8 11 11 10 11 10		0 no spacing or crowding
	Sum of distance (Space Available)	82	Sum of teeth (Space required)	82	
IPHONE Lower case ``First Set	Set distances		Teeth space		difference
	30 16 14 30		11 10 9 9 8 7 7 10 10 11		-2 crowding
	Sum of distance (Space Available)	90	Sum of teeth (Space required)	92	

IPHONE Upper case ``Second Set	Set distances		Teeth space		difference
	15 10 9 15		4 5 5 5 6 6 4 5 5 4		0 no spacing or crowding
	Sum of distance (Space Available)	49	Sum of teeth (Space required)	49	
Lower case ``Second Set	Set distances		Teeth space		difference
	14 6 6 14		6 4 4 3 3 3 3 4 4 6		0 no spacing or crowding
	Sum of distance (Space Available)	40	Sum of teeth (Space required)	40	

IPHONE Upper case ``Third Set	Set distances		Teeth space		difference
	18 11 12 18		5 5 6 5 6 6 5 6 5 5		+5 spacing
	Sum of distance (Space Available)	59	Sum of teeth (Space required)	54	
Lower case ``Third Set	Set distances		Teeth space		difference
	24.5 13.3 13.8 27.9		9.6 9.4 7.8 6.3 5.6 5.6 6.3 7.5 8.7 9.8		+2.9 spacing
	Sum of distance (Space Available)	79.5	Sum of teeth (Space required)	76.6	

Table1. Space Measurement obtained from IPhone Measurement Tool App photos for the three sets

Android	Set distances				Teeth space										difference
Upper case ``First Set	5	5.1	5	5	2.1	3	2	3	3	2	3	2			(0) no spacing or crowding
	Sum of distance (Space Available)			20.1	Sum of teeth (Space required)								20.1		
Lower case ``First Set	22	12	12	24	8	8	8	6	6	6	6	8	8	8	-2 crowding
	Sum of distance (Space Available)			70	Sum of teeth (Space required)								72		

Android	Set distances				Teeth space										difference
Upper case ``Second Set	25	17	17	25	7	8	9	8	10	10	8	9	8	7	(0) no spacing or crowding
	Sum of distance (Space Available)			84	Sum of teeth (Space required)								84		
Lower case ``Second Set	29	13	13	29	13	8	8	7	6	6	7	8	8	13	(0) no spacing or crowding
	Sum of distance (Space Available)			84	Sum of teeth (Space required)								84		

Android	Set distances				Teeth space										difference
Upper case ``Third Set	31	21	21	31	10	10	11	9	10	10	8	11	10	9	+5 spacing
	Sum of distance (Space Available)			104	Sum of teeth (Space required)								98		
Lower case ``Third Set	7.1	4	3	8	2.1	2	2	1	2	2	2	2	2	2	+3 spacing
	Sum of distance (Space Available)			22.1	Sum of teeth (Space required)								19.1		

Table2. Space Measurement obtained from **Android photo ruler App** photos for the three sets

Device	Cast Type	Space Available	Space Required	Space Analysis
conventional cast	first set upper cast	60	60	0
conventional cast	first set lower cast	64	66	-2
conventional cast	second set upper cast	76	76	0
conventional cast	second set lower cast	70	70	0
conventional cast	third set upper cast	84	79	5
conventional cast	third set lower cast	67	64	3
IPhone	first set upper cast	82	82	0
IPhone	first set lower cast	90	92	-2
IPhone	second set upper cast	49	49	0
IPhone	second set lower cast	40	40	0
IPhone	third set upper cast	59	54	5
IPhone	third set lower cast	79.5	76.6	3
Android	first set upper cast	20.1	20.1	0
Android	first set lower cast	70	72	-2
Android	second set upper cast	84	84	0
Android	second set lower cast	84	84	0
Android	third set upper cast	104	98	5
Android	third set lower cast	22.1	19.1	3

Table 3. A summary of Apps measurement for space available and Space Required

3. Result

According to *t* tests based on the differences in the values between the conventional cast and Iphone app, no significant differences in space analysis were found, as shown in Table 4. Furthermore, no significant differences were found in the space analysis *t* test obtained from the conventional cast and Android pp (Table 5). Similarly, no significant differences were found between the applications used by the Iphone and the Android system. As shown in the tables, the *t* tests found that space analysis of the Iphone app had no statistically significant measurements (1 ± 2.52) compared to a conventional cast, t (10) = 0.11, $p = 0.99$.A repeated-measures analysis of variance (one-way ANOVA) of space analysis was also performed on variance between the conventional cast and smartphone measurement apps using mobile phone *P* values and mean differences, as shown Table 6. The ANOVA test also showed that there was no statistically significant difference between the groups, as determined by one-way ANOVA ($p = 1$). A post hoc Tukey test revealed that there was no statistically significant difference for space analysis between the conventional cast, Iphone app and Android groups ($p = 1$) indicating the good measuring accuracy of all these tools, as shown Table 7.

Group Statistics

	device	N	Mean	Std. Deviation	Std. Error Mean
space analysis	conventional cast	6	1.000	2.5298	1.0328
	IPhone	6	.983	2.5143	1.0265

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
space analysis	Equal variances assumed	.001	.976	.011	10	1.000	.0167	1.4561	-3.2278	3.2611
	Equal variances not assumed			.011	10.000	.991	.0167	1.4561	-3.2278	3.2611

Table 4. *t* tests result on the differences of the values between the conventional cast and iPhone App

Group Statistics

	device	N	Mean	Std. Deviation	Std. Error Mean
space analysis	conventional cast	6	1.000	2.5298	1.0328
	Android	6	1.000	2.5298	1.0328

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
space analysis	Equal variances assumed	.000	1.000	.000	10	1.000	.0000	1.4606	-3.2544	3.2544
	Equal variances not assumed			.000	10.000	1.000	.0000	1.4606	-3.2544	3.2544

Table 5: *t* tests results on the differences of the values between the conventional cast and Android App

ANOVA

space analysis

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.001	2	.001	.000	1.000
Within Groups	95.608	15	6.374		
Total	95.609	17			

Multiple Comparisons

space analysis

Tukey HSD

(I) device	(J) device	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
conventional cast	IPhone	.0167	1.4576	1.000	-3.769	3.803
	Android	.0000	1.4576	1.000	-3.786	3.786
IPhone	conventional cast	-.0167	1.4576	1.000	-3.803	3.769
	Android	-.0167	1.4576	1.000	-3.803	3.769
Android	conventional cast	.0000	1.4576	1.000	-3.786	3.786
	IPhone	.0167	1.4576	1.000	-3.769	3.803

Table 6. one-way ANOVA tests results on the differences of the values between the conventional cast and Smart Phones App

ANOVA

space available

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	113.921	2	56.961	.100	.905
Within Groups	8521.855	15	568.124		
Total	8635.776	17			

Multiple Comparisons

space available

Tukey HSD

(I) device	(J) device	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
conventional cast	IPhone	3.5833	13.7613	.963	-32.161	39.328
	Android	6.1333	13.7613	.897	-29.611	41.878
IPhone	conventional cast	-3.5833	13.7613	.963	-39.328	32.161
	Android	2.5500	13.7613	.981	-33.195	38.295
Android	conventional cast	-6.1333	13.7613	.897	-41.878	29.611
	IPhone	-2.5500	13.7613	.981	-38.295	33.195

ANOVA

space required

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	119.764	2	59.882	.107	.899
Within Groups	8372.747	15	558.183		
Total	8492.511	17			

Multiple Comparisons

space required

Tukey HSD

(I) device	(J) device	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
conventional cast	IPhone	3.5667	13.6404	.963	-31.864	38.997
	Android	6.3000	13.6404	.890	-29.131	41.731
IPhone	conventional cast	-3.5667	13.6404	.963	-38.997	31.864
	Android	2.7333	13.6404	.978	-32.697	38.164
Android	conventional cast	-6.3000	13.6404	.890	-41.731	29.131
	IPhone	-2.7333	13.6404	.978	-38.164	32.697

Table 7: one-way ANOVA tests results on the differences of the values between the conventional cast and Smart Phones App for space available and space analysis measurements

4. Discussion

The result of the space analysis was found to be the same when comparing the conventional cast model with the smartphone app measurement programs. However, findings show differences between the "space required" and the "space available" measured values when comparing the conventional cast with the smartphone apps. The absolute measurement values were larger in the smartphone photos than the actual physical measurement on the conventional cast model. This results in slight variability and difference in the absolute measured values of the digital techniques; however, no impact on the final space analysis results was observed between the conventional and the digital techniques. Although the difference in absolute measurement values cannot be attributed to the differences in the alginate impressions' pouring time as reported in Leifer *et al.*, it may be due to the scaling methods implemented in the smartphone apps. The slight shrinkage of the impressions may also be a probable reason for the differences[12]. Furthermore, the differences in the measurements might be attributed to the ability and experience of the user in using the smartphone apps, the angulations that the image was taken from, the height, the accuracy and quality of the program used, and the time taken, [13-18]. Moreover, reading errors can result while recording the traditional physical measurements of the conventional cast model due to visual approximation. According to Santoro *et al.*, when repeated by the same operator, the margin of error in measuring the plaster cast can have an average of 0.2 mm 14. It is worth mentioning here that a trial was also conducted on photos of patients' mouths taken directly using smartphone apps. We found that the space analysis results were identical to the physical measurements taken from the cast model. However, the implementation of the technique of capturing photos of a patient's mouth was considerably more difficult. Furthermore, the quality of the image obtained from the oral cavity, a dark area, was particularly poor. Considering the cons for using smartphone apps for space analysis, we may conclude the following. The time executed to measure a conventional cast model using smartphone apps (i.e. digital techniques) is significantly longer than that needed for the conventional direct method. This is due to the difficulty in the manipulation, and to the average quality of the obtained pictures. The measurement accuracy depends to a certain degree on the skills and familiarity of the user of the smartphone apps, as well as the accuracy and quality of the smartphone device and its apps programs. Even though the result of the space analysis of both techniques was the same and no significant differences were found, the applications of smartphone apps for space analysis still require further scrutiny to establish whether they are appropriate for use as established scientific and medical techniques. Therefore, further investigations and trials should be conducted to assess the accuracy and reliability of different apps programs for smartphones produced by various software developers.

5. Conclusion

The accuracy of the space analysis of conventional techniques and the measurement applications in the Iphone or Android software was found to be similar. There were, however, significant differences in the available and required space measurements made via digital photos in comparison to the direct physical measurement of the plaster casts; the time taken to carry out the digital photo measurements was much longer. Therefore, further investigations should be conducted to assess the accuracy and reliability of the apps programs of smartphones, as the absence of hard evidence that using digital photos of conventional cast models provides accurate results and its implementation relative difficulty for space analysis, may make dentists reluctant to change their long-established practice of the physical measurement technique. However, it may still prove useful in supporting a decision-making consideration for an alternative course of action, should medical practitioners need to do so.

6. References

1. Health Information Technology. Federal Health IT Strategic Plan 2015-2020. Washington, DC: Department of Health and Human Services, 2015.
2. 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(5):128.
3. Ventola CL. Mobile devices and apps for health care professionals: uses and benefits" P & T Journal. May. 2014; 39(5):356-364.
4. Saddik B, Barakah DM, Aldosari B. A Study of PDA and Smartphone Adoption Rates at King Saud Medical City Hospitals. Proceedings of the 6th IEEE International Symposium on Medical Information and Communication Technology, La Jolla, USA, 2012.
5. Musich D, Ackerman J. The Catenometer: A reliable device for estimating dental arch perimeter, American Journal of Orthodontics. 1973; 63(4):366-375.
6. Mullen S, Martin C, Ngan P, Gladwin M. Accuracy of space analysis with e-models and plaster models, American Journal of Orthodontics and Dentofacial Orthopedics. 2007; 132(3):346-352.
7. Martinson B, Ryden H. The holodent system, a new technique for measurement and storage of dental casts. Am J Orthod Dento facial Orthop. 1992; 102:113-9.
8. Romeo A, Canal F, Roma M, de la Higuera B, Ustrell JM, von Arx JD. Holograms in orthodontics: a universal system for the production, development, and illumination of holograms for storage and analysis of dental casts. Am J Orthod Dentofacial Orthop. 1995; 108:443-7.
9. Schirmer UR, Wiltshire WA. Manual and computer-aided space analysis: a comparative study. Am J Orthod Dentofacial Orthop. 1997; 112:676-80.
10. Anand Kumar A, Abraham Phillip, Sathesh Kumar, Anuradha Rawat, Sakthi Priya, V Kumaran. Digital model as an alternative to plaster model in assessment of space analysis. J Pharm Bioallied Sci. 2015; 7(2):465-S469.
11. A Bell, AF Ayoub, P Siebert. Assessment of the accuracy of a three dimensional imaging system for archiving dental study models. Journal of Orthodontics. 2003; 30:219-223.
12. Leifert M, Efstratiadis S, Cangialosi T. Comparison of space analysis evaluations with digital models and plaster dental casts. American Journal of Orthodontics and Dentofacial Orthopedics. 2009; 136(1):161-164.
13. Johal AS, Battagel JM. Dental crowding: a comparison of three methods of assessment. Eur J Orthod. 1997; 19:543-51
14. Santoro M, Ayoub ME, Pardi V, Cangialosi TJ. Mesiodistal; Crown dimensions and tooth size discrepancy of the permanent dentition of Dominican Americans. Angle Orthod. 2000; 70:303-7.
15. Nouri M, Abdi AH, Farzan A, Mokhtarpour F, Baghban AA. Measurement of the buccolingual inclination of teeth: manual technique vs 3-dimensional software. Am J. OrthodDento facial Orthop. 2014; 146:522-9.
16. Rossini G, Parrini S, Castroflorio T, Deregibus A, Debernardi C. Diagnostic accuracy and measurement sensitivity of digital models for orthodontic purposes: A systematic review. American Journal of Orthodontics and Dentofacial Orthopedics. 2016; 149(2):161-170.
17. Goonewardene RW, Goonewardene MS, Razza JM, Murray K. Accuracy and validity of space analysis and irregularity index measurements using digital models. Aust. Orthod J. 2008; 24:83-90.
18. Mayers M, Firestone AR, Rashid R, Vig KW. Comparison of peer assessment rating (PAR) index scores of plaster and computer-based digital models. Am J Orthod Dentofacial Orthop. 2005; 128:431-4.