

CLINICAL STUDY

Digital and manual cephalometric analysis

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Abstract: *Objectives:* To compare the manual and digital cephalometric analyses and to research a new procedure of analog cephalogram digitalization.

Methods: 40 repeated measurements were used to evaluate the reproducibility and reliability of both methods. The analog x-ray was CHIRALUX2, the digital camera used was Canon PowerShot G5 and the digital tracing was done by Dolphin imaging version 10. The sample dispersion has been evaluated for each of the monitored cephalometric variables (SNA, SNB, ANB, PP/ML, inter-incisal angle and Wits). The difference of sample dispersion was tested (Morgan-Pitman). Four doctors processed 100 random analog cephalograms in total and evaluated them in a way established by Bland and Altman.

Results and conclusion: Validity and reproducibility of analyses carried out manually and digitally is in high mutual correlation and therefore the software analysis can fully substitute the manual method. The dispersion of values in repeated measurements was higher in manual method and therefore we consider the digital method more accurate (Fig. 4, Tab. 1, Ref. 15). Full Text (Free, PDF) www.bmj.sk.

Key words: digital cephalometric analysis, Dolphin imaging, analog cephalogram, camera digitalization.

In orthodontics, the cephalogram is the crucial diagnostic component. It is essential for correct treatment assessment and later for evaluation of the effect of the therapy. The cephalometric analysis is performed on cephalograms and can be done manually or by software. The digital evaluation of cephalometric analysis supplemented with 2D-profile photo of the patient provides an overview of changes caused by therapy. It can be done also as virtual simulation prior to the therapy. This is why the aspect of measurement errors is so important and cephalogram can detect even the slightest changes achieved by treatment (1).

Slovak orthodontists still prefer conventional manual analysis. One of the reasons is that manual analysis (Fig. 1) was proved in the previous century as scientifically adequate (2, 3). Another reason is the inevitability of financial investment in software

application as well as the lack of comparative clinical trials researching the advantages of digital analysis.

The most frequent orthodontic patients are children and adolescents and their susceptibility to radiation can highly benefit from diagnostic methods that decrease the radiation dose. With the use of digital dental x-ray, this reduction can reach 90 % in comparison with analog x-ray. This significant reduction is possible not only on account of more sensitive sensors but also as a consequence of software “post-processing” (5).

However, analog dental x-ray machines still prevail in Slovakia. Also the vast majority of all archived orthopantomographs and cephalograms are in analog format. Any long-term retrospective study in dentistry must face this fact. In order to prepare a treatment plan it is necessary to analyse the patient cephalogram. This can be done manually or by software, and the cephalogram can be digital or analog. It is typical for a dental clinic to use either digital x-ray and software or analog x-ray with conventional manual cephalometric analysis. In this research, both types of cephalometric analysis are compared.

Material and methods

The comparison is based on evaluation of 100 analog cephalograms. The software used for analysis was the Dolphin Imaging Software (Version 10.0) funded from Grant of Comenius University 108/2007 and St. Elisabeth Institute of Oncology (Fig. 2). Similar study has been done by Department of Orthodontics in GKT Dental Institute, Kings College (6). This study from 2005 indicates that Version 8.0 of Dolphin Imaging Software needs to

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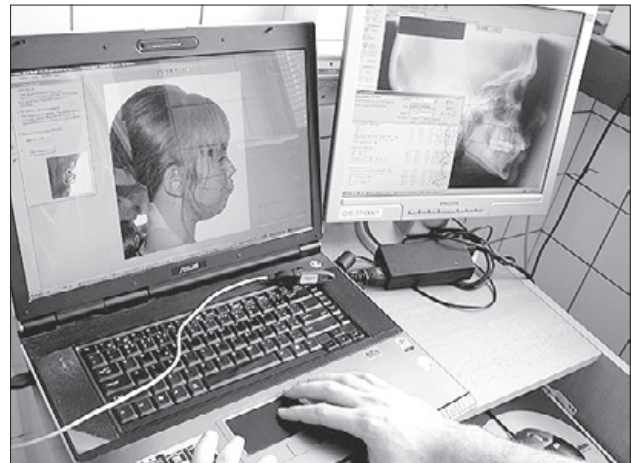


Fig. 1. Example of manual method of cephalometric analysis (left) and digital method (right).

be re-assessed for software errors that may result in clinically significant miscalculations.

The overall goal of the research was to compare the conventional method of manual tracing with a computer method, where 100 original analog lateral cephalograms were digitized by digital camera and analyzed using Dolphin Imaging Software. The hypothesis was that the manual analysis is less accurate than the digital one.

Our first objective was to evaluate whether the method of cephalograms' digitalization by digital camera is scientifically reliable and accurate and to compare the reproducibility and reliability of manual and digital methods. If the digital camera could substitute a table scanner in the process of digitalization, it would improve the chances of spreading the digital cephalometric analysis into the clinical practise. Slovak dental clinical practice is mostly private, and avoiding the necessity of table scanner would

be welcome. The digital camera with dental ring light is already a common part of orthodontic equipment not only for basic intraoral and extraoral diagnostics but also for forensic reasons. Also in many other fields of dentistry, the digital dental photography is a common diagnostic element. In some other sophisticated clinical fields for example maxillofacial surgery or orthodontics treating cleft anomalies is the digital camera crucial (11).

Our second objective was to investigate cephalograms of random 100 patients for significant difference between both series of values resulting from manual and digital processings.

First objective: One cephalogram of average quality was randomly chosen. All analog cephalograms were made by analog x-ray CHIRALUX2. Four different doctors have photographed the cephalogram with a ruler on a conventional illuminator five times. Twenty pictures were taken. The digital camera was Canon

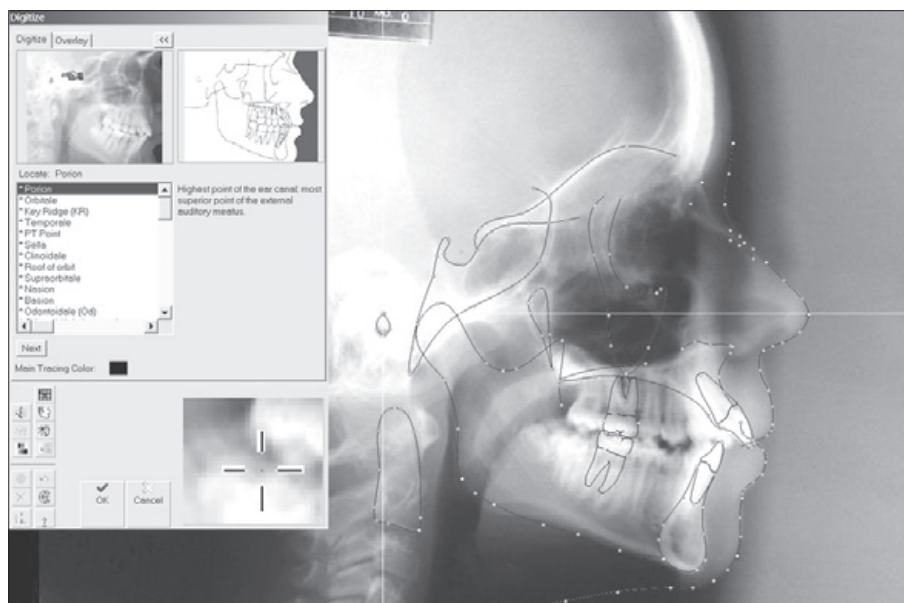


Fig. 2. The interface of the orthodontic analytical software Dolphin imaging.

$$\left[\frac{n \cdot \bar{S}_n^2}{\chi^2_{n-1, \frac{\alpha}{2}}}, \frac{n \cdot \bar{S}_n^2}{\chi^2_{n-1, 1-\frac{\alpha}{2}}} \right]$$

where is

$$\bar{S}_n^2 = \frac{1}{n} \sum_{i=1}^n (\bar{X}_n - X_i)^2 \quad \text{and} \quad \bar{X}_n = \frac{1}{n} \sum_{i=1}^n X_i$$

Fig. 3. The confidence interval assessment for value dispersion at the significant level.

PowerShot G5 – 5megapixel in resolution 2592x1944pixels. To compensate the possible fish-eye distortion the camera was placed on a stand at a distance of exactly 50 cm and its optics was zoomed to the cephalogram. Optic axis of the camera was perpendicular to the plane of the cephalogram. Between each shot of the digital camera, the construction of the stand, camera and illuminator were moved. Each of the images was analyzed digitally. The digital tracing was done by Dolphin imaging version 10 (Fig. 2). The original cephalogram was analyzed 20 times in total, namely five times by four different doctors. The sample dispersion has been evaluated for each of the monitored cephalometric variables (SNA, SNB, ANB, PP/ML, inter-incisal angle and Wits). The normality of the values was statistically verified (Machado). The difference of sample dispersion was tested (Morgan-Pitman test). Figure 3 shows the confidence interval assessment for value dispersion at the significant level α . Figure 4 shows the marginal variability test (Morgan-Pitman). If the hypothesis on Figure 4 is correct, we reject the hypothesis that the dispersions are equal at the significant level α . If the digital method has a smaller dispersion, it is more accurate. The measurements were evaluated in MS Excel.

Second objective: Four doctors processed 100 random analog cephalograms in total. Each cephalogram was analysed manually and also in the software. 200 cephalometric analyses were made in total and six followed parameters were extracted. The range of patients' age was from 11 to 20 years. The data were from the period from October 2006 to November 2007. All cephalograms shared the same technical properties as described in the first objective.

When comparing clinical measurements gained by an older and well-established method with a newer innovative method it is necessary to research their correlation. It is essential to decide if the new method could replace the older one. In this study, the data compared are of unknown true values. In case of calibration method, the already known values are measured with a new method. The result is compared with these known values.

The reliability of both analyses in our study was evaluated in a way established by Bland and Altman (4). This statistical method allows a simple estimation of the agreement between two measurements of an identical variable. For each followed parameter on a particular cephalogram the difference of pair values is in correlation to their average. If both methods are in ideal agreement, the point lies in the horizontal line (average) at zero. The deviation is represented by the offset of the points from this

$$r = \frac{\sum_{i=1}^n X_i Y_i - n \bar{X}_n \bar{Y}_n}{\sqrt{\sum_{i=1}^n X_i^2 - n(\bar{X}_n)^2} \sqrt{\sum_{i=1}^n Y_i^2 - n(\bar{Y}_n)^2}}$$

$$T = \frac{\bar{S}_{n_1}^2 - \bar{S}_{n_2}^2}{2\bar{S}_{n_1}^2 \bar{S}_{n_2}^2} \sqrt{\frac{n-1}{1-r^2}}$$

If the Abs(T) > $t_{n-2, \frac{\alpha}{2}}$ we reject the hypothesis that the dispersions are equal at the significant level α .

Fig. 4. The Pitman-Morgan test and the hypothesis.

line (average). The confidence interval is represented by the array that includes 95 % of normally distributed values. The comparison of the confidence interval with the clinically given value of standard deviation for given cephalometric parameter reveals the clinical significance of the differences. If the differences between two measurements within the interval are not clinically significant, the digital analysis can substitute the manual method.

Six evaluations were calculated for each followed parameter while each calculation represents the difference between two methods in relation to the average of that particular parameter. Value $p < 0.05$ has been considered for statistical significance. The study uses the standard deviation values for cephalometric parameters published by Kaminek in 2001 (7). The standard deviation value for PP/ML was taken from Dolphin imaging software. ($SNA = 82 + 3.5$ $SNB = 80 + 3.5$ $ANB = 2 + 2.0$ $inter-incisal\ angle = 127 + 8.5$ $Wits = 0mm + 2.0$)

Results

In consideration of method accuracy, the confidence interval for dispersion of values was evaluated in repeated measurements. The hypothesis of lower accuracy of the manual method has been confirmed. Summary comparison of results in followed parameters in manual and digital analyses I described in Table 1. The linear parameter Wits (mm) appeared the greatest problem as it was in contrast to other angular parameters more sensitive to low quality of the image. In addition, the rounding during manual measurement affected its value dispersion. After the comparison the range of confidence interval is 5.23 mm.

The confidence interval at the level of significance of 0.05 for all the other parameters did not exceed the clinical intervals. Results also confirmed that the accuracy of digitizing method is scientifically adequate and digital camera, if used in described procedure, could substitute a table scanner.

Digital radiodiagnostic approach is still not common in many orthodontic practices where former analog x-ray is still used. It is more frequently used with complementary software post-pro-

cessing. Digital camera has become the crucial orthodontic equipment whereas scanner has not. Using digital camera for digitalization might be found easier and much faster. The results show that our technique of digitalisation is significantly reliable at the 95 % level (method error). The distortion between the original and the digitized images showed vertical enlargement of 0.3 mm and horizontal reduction of 0.1 mm. Comparing the standard deviations of the differences, the manual tracing proved more reliable for SNA.

Discussion

A subsidiary task to the research objectives was to evaluate the most dissimilar cephalometric variable between manual and digital series. Some partial results of the research were published and presented in the European Orthodontic Symposium in Lisbon (14) and Conference of postgraduate students in Medical faculty Bratislava (15). All statistical analyses were designed and coordinated by professional statistician.

Manual analysis is not only more time consuming but also allows more measurement errors caused by doctor. The reproducibility of cephalometric points in conventional method on paper in comparison to analysis of digital image was quite controversial for a long time. Complicated process to obtain a digital record of analog x-ray, loss of data during digitalization resulting in reduced quality of the image or complicated and not sufficiently tested software environments made the relative advantages of software analysis disputable in the past. Nowadays due to technology advancement and necessity of data mobility, the manual method is becoming a handicap. In 2007, Sayinsu carried out a research comparing the cephalometric analyses on scans (with 300 dpi) and original cephalograms (8). His research confirmed the reproducibility of measurements with analytical software Dolphin Imaging and conventional analysis were in significant correlation. His research also supported the significance of digitalization for archiving, mobility and graphical post-processing of cephalograms (*secondary increasing of contrast and sharpness*). However, his research was probably for its procedure of digitalization (*scanning and pointing with graphic pen*) unsuccessful in evaluating the method accuracy. A similar research was carried out by Collins (9) who on 20 cephalograms confirmed that analysis of the digital cephalogram is comparable with that of the scanned one. His research showed the unreliability in evaluating the linear parameters. Both research studies partially correlate with our results, however when involving smaller sets of patients and different procedures of digitalization. Results of both studies agree with our finding of problematic linear parameter evaluation. In our study, it is the Wits cephalometric parameter. The most probable reason is the high variability in analog x-ray quality. The results encourage to similar research in the field of evaluating the original digital cephalograms.

Conclusion

The validity and reproducibility of analyses carried out manually and digitally is in high mutual correlation and therefore the

software analysis can fully substitute the manual method. The dispersion of values in repeated measurements was higher in the manual method and therefore we consider the digital method more accurate. In respect to speed, accuracy and later scientific and clinical mobility of the data, the software cephalometric analysis can be suggested for routine use.

Although some distortion was found, the relatively small horizontal and vertical discrepancies were deemed clinically insignificant. The results showed the digital method more accurate and more precise than the classical manual cephalometric analysis. Our method of digitalization, i.e. using the digital camera, is scientifically reliable and exact.

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