Comparative Reliability of Different Traditional and Computerized Cephalometric Analyses

Procjena pouzdanosti različitih tradicionalnih i računalskih kefalometrijskih metoda

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Acta Stomatol Croat
1996; 103—108

Summary

The reliability of two traditional and two computerized cephalometric analyses was comparatively examined. Thirty radiograms were analysed twice with all four analyses. On 18 selected variables of each of the analyses average differences and method errors were evaluated. The results indicate that there are no significant differences between the traditional, indirect method with conventional cephalometric tracing and direct computer analysis. The examinations undertaken with an indirect computed method, during which the cephalometic landmarks are fixed on the screen of the computer, revealed significant differences. The obtained values indicating the inclination of the incisors were found to differ the most. The least significant differences of all cephalometric methods was found in linear landmarks, specifying the upper and lower incisor position.

Key words: *cephalometrics, method differences, method error*

ORIGINAL SCIENTIFIC PAPER
Primljeno 10. srpnja 1996.
Received: July, 10. 1996.

Introduction

Earlier cephalometric analyses in orthodontics were performed directly on radiograms using white ink to demonstrate the relevant anatomic structures and landmarks and to subsequently carry out measurements (1,2). Björk and Solow (3) describe the method of direct analysis on radiograms by application of an adequate stave on acetate foils without marking any details. However, the most frequent procedure was to measure the established parameters drawn on semi-transparent tracing paper.

The developments of computer science with ever increased and improved data processing led to the introduction of various computed cephalometric analyses for orthodontic diagnoses (4,5,6,7,8,9). In many orthodontic departments and practices today traditional cephalometric analyses have been replaced by computed processing, which offers a number of advantages: more rapid and precise identification of marks, exact evaluation and processing of data, the option of statistical procedure and a common documentation and data storage system.

The precision of reading cephalometric landmarks and furthermore, the value of an analysis in general, depends on wide range of factors, such as the quality of the radiogram, the examiner's experience and mostly the ability of the system to reliably reproduce cephalometric marks, angles and distances. Therefore the choice of method is extremely important (10,11,12).

Our study was designed to compare four different methods - two traditional ways of tracing and two computerized cephalometric system - and finally to evaluate the reliability of each method.

Materials and Methods

Lateral cephalograms of 30 examinees of the Department of Orthodontics, Zagreb School of Dental Medicine, and 30 radiograms of patients of the Department of Orthodontics, Johannes Gutenberg - University, Mainz, were examined. All radiograms were analyzed by an orthodontist twice during two different periods of time. The sample of Zagreb radiograms was studied by application of the following three methods:

Method 1 - Traditional mode of measurement on tracing paper with a ruler and protractor, achieving precision of 0.5 degrees and 0,5 millimeters.

Method 2 - Measurement directly on the radiograms, applying the parallel stave system on acetate foils, according to the method by Björk and Solow, with precision of 0.5 degrees and 0.5 millimeters.

Method 3 - Computed analysis with images being conveyed from the negatoscope to the screen with the help of a high resolution camera. The cephalometric points are then marked by a mouse. The size of the pixel, and consequently the solution, was 0.39 x 0.50 millimeters.

By all these three methods, eighteen variables according to the roentgencephalometric analysis "Zagreb 82 MOD" (15) were measured (Table 1, Fig.1). Method 4 was slightly different from the previous ones.

Method 4 - The computerized evaluation system PorDios (Purpose On Request Digitizer Input Output System; I.o.O.C., Aarhus, Denmark), used in the Department of Orthodontics at the Johannes Gutenberg - University, Mainz, enables direct digitization on a radiogram in a given order with on optical digitizer KD 4300 (Graphitec Corporation).

From a total of 29 analysis parameters 18 were selected, out of which 15 were the same as in the previous three analyses, and three were thematically similar (Table 2).

Table 1 *Mean values (MEAN), standard deviations (SD) and method errors (ME) of double determinations for all variables of method 1,2 and 3.*

Tablica 1. *Srednje vrijednosti (MEAN), standardni otkloni (SD) i metodske pogreške (ME) dvostrukog mjerenja svih varijabla u postupcima 1, 2 i 3.*

Method 1				Method 2			Method 3		
Variable	MEAN	SD	ME	MEAN	SD	ME	MEAN	SD	ME
1. n-ss : ss-pg	.95	.82	.75	.75	1.02	.88	1.46	.86	1.10
2. n-s : sp-pm	1.00	.79	.80	.70	.60	.64	1.46	1.23	1.33
3. s-n-ss	.57	.50	.28	.67	.59	.62	1.68	.99	1.37
4. s-n-sm	.52	.53	.27	.48	.56	.58	1.37	.90	1.14
5. ss-n-sm	.50	.42	.20	.70	.62	.65	.92	.61	.77
6. n-s-gn	.48	.50	.23	.87	.80	.82	1.29	.97	1.14
7. sp-pm : m-go	.82	.66	52	1.07	.99	1.02	1.28	.91	1.10
8. n-s-ar	.95	.72	.83	1.07	.78	.93	1.49	.89	1.22
9. s-ar-go	1.50	.91	.22	1.83	1.20	1.54	1.58	.97	1.30
10. m-go-ar	.82	.59	.69	.88	.98	.90	1.13	.84	.99
11. 8+9+10	1.02	.98	.97	1.92	1.34	1.66	1.13	.75	.95
12. n-go-m	.45	.38	.17	.78	.78	.75	.96	.72	.74
13. n-go-ar	.77	.69	.49	1.43	1.05	1.20	1.28	.81	1.06
14. 1 : sp-pm	1.15	.91	1.06	1.93	1.50	1.71	1.52	.78	1.20
15. 1 : m-go	1.50	1.41	1.44	1.30	1.10	1.19	1.50	.97	1.25
16. 1 : 1	1.45	1.09	1.27	1.85	1.61	1.72	3.59	1.57	2.76
17. 1 : n-ss	.50	.37	.18	.38	.36	.37	.74	.48	.53
18. 1 : n-sm	.47	.45	.47	.47	.47	.47	.63	.42	.48

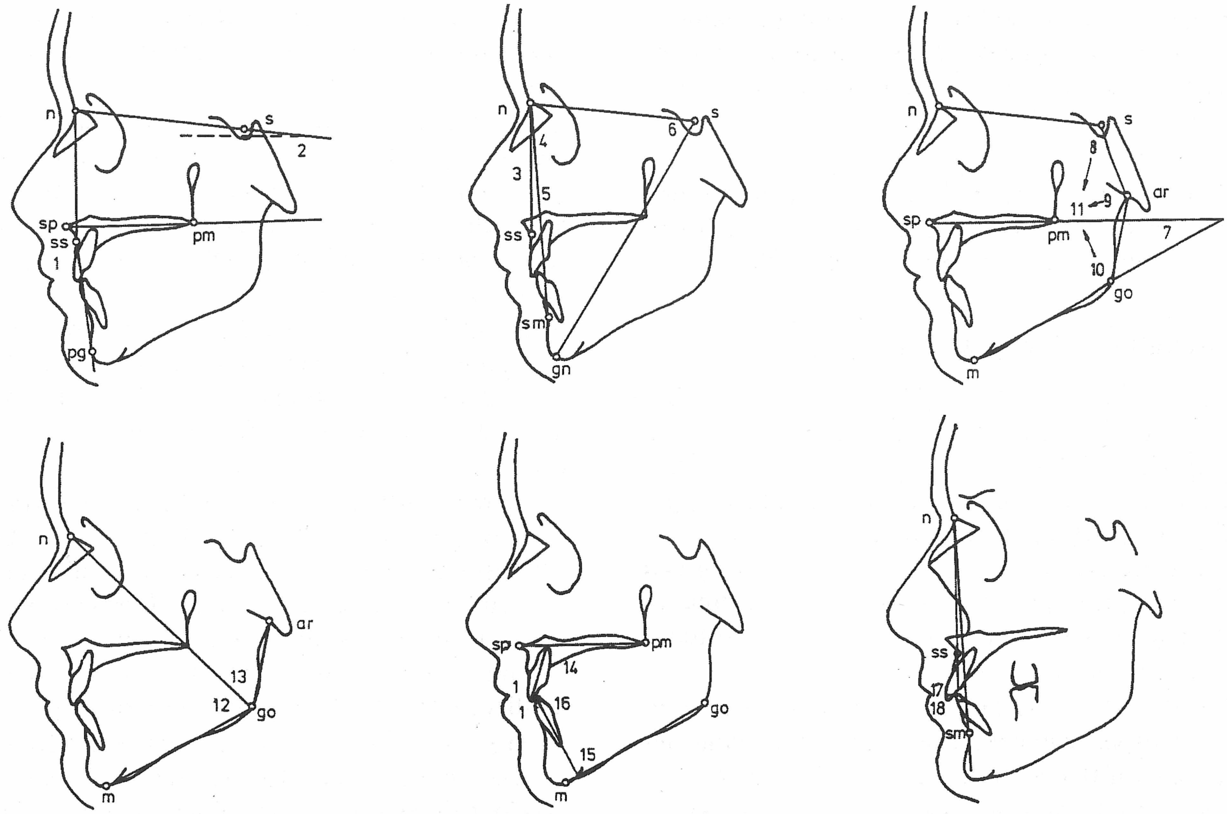

Figure 1 *Survey of the 18 variables analyzed for method 1,2 and 3.*
Slika 1. Pregled 18 varijabla određenih u postupcima 1, 2 i 3.

Table 2 *Mean values (MEAN), standard deviations (SD) and method errors (ME) of differences of twofold analyses for selected variables by method 4.*
Tablica 2. *Srednje vrijednosti (MEAN), standardni otkloni (SD) i metodske pogreške (ME) dvostrukog mjerenja odabranih varijabla u postupku 4.*

Method 4			
Variable	MEAN	SD	ME
1. SNA	0.51	0.50	0.50
2. SNB	0.31	0.28	.30
3. ANB	0.30	0.24	0.24
4. T	1.16	0.89	1.04
5. B	0.87	0.95	0.84
6. Inklination OK 1	0.90	1.05	0.96
7. Inklination UK 1	0.91	0.72	0.81
8. Interinzisalwinkel	1.23	1.20	1.22
9. Y	0.23	0.14	0.20
10. Sella	0.51	0.43	1.45
11. Artikular	1.08	1.26	1.16
12. Gonial	0.82	0.59	0.66
13. Summe nach Björk	0.59	0.44	0.48
14. Go 1	0.56	0.36	0.46
15. Go 2	0.42	0.36	0.37
16. Konvexitat	0.54	0.17	0.46
17. OK 1 zu NPo (mm)	0.33	0.28	0.28
18. UK 1 zu NPo (mm)	0.26	0.20	0.22

The results of all four methods were statistically processed by calculating the arithmetic means and standard deviations as well as the method errors of differences of both measurements for every variable. The method error was calculated according to the formula $ME = \sqrt{(XA - XB)^2 \div 2N}$ (ME = method error; XA = first measurement of a variable; XB = second measurement of the same variable; N = number of all radiogram examined).

Between method 1 and method 3, where we realized the most differing values of all examinations, the differences of the arithmetic means-differences were tested for all parameters with statistical t-test.

Results

The results of statistical evaluation of the basic data for all methods applied are presented in Tables 1 and 2.

The greatest differences and method errors of method 1 were found in variables estimating the inclination of the lower incisors in relation to the basal line of the lower jaw and the interincisal angle (ME -1.44, -1.27). On the other hand the lowest differences of values were registered for the n - to - m angle (0.37).

In method 2, the most significant method error could be demonstrated for the interincisal angles (1.72), whereas the smallest was found for determination of the upper incisor position (0.37).

The range of method errors of method 3 covers the highest values for the interincisal angle (2.76) to the lowest variables for the position of the lower incisor (0.48).

For the computerized method 4, the most significant method error was observed in the interincisal angles (1.22), the lowest in the linear variable indicating the position of the lower incisor (0.22).

Between the conventional tracing method 1 and the indirectly computerized method 3 the differences of their arithmetical means was statistically significant for most variables (Table 3).

Table 3 *Tests of the arithmetical means of differences of the double checks for all variables of method 1 and 3.*
Tablica 3. *Pregled razlika srednjih vrijednosti dvostrukog mjerenja svih varijabla u postupcima 1 i 3.*

Variable M1-M3	Paired Diff.				
	Mean	SD	t	df	2-tail Sig
V1	-.50	1.06	-2.63	29	.014 *
V2	-.46	1.28	-1.97	29	.058
V3	-1.11	1.02	-5.96	29	.000 **
V4	-.85	.99	-4.73	29	.000 **
V5	-.42	.76	-3.05	29	.005 **
V6	-.81	1.02	-4.33	29	.000 **
V7	-.46	1.21	-2.12	29	.043 *
V8	-.53	1.32	-2.23	29	.034 *
V9	-.08	1.02	-.45	29	.657
V10	-.31	1.03	-1.69	29	.102
V11	-.11	1.20	-.53	29	.598
V12	-.51	.85	-3.30	29	.003 **
V13	-.51	1.06	-2.67	29	.012 *
V14	-.36	.96	-2.10	29	.045 *
V15	.00	1.74	.01	29	.992
V16	-2.13	2.01	-5.81	29	.000 **
V17	-.74	.87	-4.66	29	.000 **
V18	-.16	.62	-1.47	29	.153

Discussion

The reliability of the cephalometric marks and the ability to reproduce them repeatedly depends very much on the choice of method (10,11,12). Further differentiation of various landmarks prompted several authors to conclude that not all marks are equally reliable (10,11,12).

For the traditional way of indirect tracing, method 1, the lowest difference between the first and the second measurements could be demonstrated for the position of the incisors with regard to the apical mandibular bases (variables 17 and 18). A high degree of reliability was also seen for the clinically important parameters, indicating the sagittal relation of both jaws to the cranial base (s-n-ss; s-n-sm; s-n-gn).

According to our results, determination of the axial inclination of the upper and lower incisors, and therefore determination of the interincisal angle provided some difficulties, which correlated to the relatively high values of method errors (1.0 - 1.44 of variable 14- 16). Obviously the superposition of several teeth roots, as well as the not always clearly defined periodontal spaces traced indirectly on slightly opalescent tracing paper, can induce significant alterations of these measured parameters.

Direct tracing on a film, method 2, could be more accurate than indirect measurement drawn on tracing paper. As we proceeded according to the suggestions Björk and Solow (3), performing the evaluation of the lateral cephalograms with a stave system on acetate foils, the errors were somewhat more significant than by method 1. So given lengths are registered without any markings. The most significant errors were observed in variables assessing the inclination of the incisors with method errors up to 1,72 (variable 14,15,16). The results of this study are similar to those obtained by Solow (16), who even stated a method error of 2.62 for the interincisal angle. He attributed the restricted reliability to difficulties in defining the apices of the upper and lower incisors and, consequently the interincisal relation. On the other hand, the lowest method errors were seen again for the parameters indicating the position of the incisors (variable 17 and 18).

When a computerized method is applied, during which the lateral cephalogram is conveyed to the screen via a camera and the cephalometric points are marked there with a mouse, evaluation showed greater differences and method errors of all variables compared to the other methods. Nevertheless, for method 3 the lowest method errors could also be stated for the assessment of the upper and lower incisors (o.53 and 0.48) and the highest ones for the interincisal angle (2.76). We explain the significantly higher scattering of values by method 3 with the size of the pixel matrix used to mark the cephalometric points, slight differences between the arrow position seen on the screen and the finally recorded landmark position.

The computerized method 4 of the Department of Orthodontics at Mainz University, by which cephalometric marks directly recorded on the radiogram, leads to significantly smaller method errors. Also in method 4, the greatest error has been found to be for the interincisal angle (1.22), and the least for the Y-angle (0.20). Several authors demonstrated that computerized localization of points basically is not more accurate than traditional tracing methods (11,13,14). According to our results, this statement cannot be supported. If the problem of subjective error in entering the defined cephalometric marks is minimized, as in method 4, computerized cephalometry is a valuable tool in orthodontic diagnostics. Not to mention the numerous advantages of computer analysis for storage and processing of data as well as communication.

Interestingly, all applied methods showed the greatest method errors when indicating the inclination of the upper lower incisors. This correlates with the findings of a few other authors. Droschl (17) found differences in the evaluation of the upper incisor inclination of up to 0.9 degrees and of the lower incisors up to 1.6 degrees, mainly due to differences in determining the position of the incisor apices. Richard son (11) also saw differences in fixing the horizontal and vertical apex position independent of the method of measurement. Kulmer et al. (14) realized only insignificant errors when he assessed the interincisal angle in comparing traditional methods with computerized procedures. Obviously, in this anatomical region, the ability to reproduce intraosseous cephalometric landmarks is more dependent on morphologic assumptions than from the method of evaluation.

On the other hand all methods show exact results, where clearly defined landmarks are situated in well delimited cortical structures, or at a bone-soft tisue borderline, such as the Y angle defined by easily perceptible landmarks such as n, s and gn.

The precision of the traditional method 1 is closest to the direct computerized method 3. Minor differences of the method errors in determination of SNA-, SNB- and ANB-angles might be due to interindividual differences in handling of the system.

Conclusions

- When comparing the results and evaluating the method errors of indirect and direct, traditional and computerized cephalometric procedures, we registered differences among the methods, as well as differences between the variables of method errors within one method. In our study, differences between the methods applied indicate similarity of the excellent results between the traditional cephalometry, with indirect measurement on tracing paper (method 1), and the directly computerized cephalometric analysis (method 3). Method errors of the indirect computerization (method 3) were significantly higher.

- We found grater differences of measurements for the landmarks, which were for anatomical reasons difficult to localize, independent of the methods applied. On our study, determination of the apices of upper and lower incisors was most unreliable, so the parameters dependent on these landmarks, like the inclination of the incisors or the interincisal angles, could be most different. On the other hand, clearly defined marks of easily perceptible osseous structures, such as n, s, gn, ss. sm and the parameters deduced from them, were of great reliability .

PROCJENA POUZDANOSTI RAZLIČITIH TRADICIONALNIH I RAČUNALSKIH KEFALOMETRIJSKIH METODA

Sažetak

Usporedbom dviju tradicionalnih i dviju računalskih kefalometrijskih raščlamba istraživana je njihova pouzdanost. Na uzorku od 30 rentenograma analizirano je po 18 odabranih kefalometrijskih varijabla. Svi rentgenogrami analizirani su dva puta u različitim razdobljima i izračunate su srednje razlike te metodske pogreške za svaku varijablu.

Rezultati upućuju na zaključke da nema većih razlika između tradicionalne posredne metode i suvremene izravne računalske raščlambe. Veće su razlike dvostrukih mjerenja registracije kod primjene posredne računalske metode gdje se kefalometrijske točke označavaju na monitoru računalskog sustava. Najveće su metodske pogreške opažene kod varijabla kojima se procjenjuju inklinacije inciziva, a najmanje kod linearnih varijabla za procjenu njihovih položaja kod svih primjenjenih metoda.

Ključne riječi: *kefalometrija, pouzdanost metoda, metodske pogreške*

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