

# Digital Radiographic Analysis References:

1. Practicing Chiropractors Committee on Radiology Protocols, Chapter II - Chiropractic Guideline for Spine Radiography for the Assessment of Spinal Subluxation in Children and Adults, B - Position on Computerized Analysis of Radiographs: The Current PCCRP Guideline Panel considers computer assisted radiographic analysis to be a reliable and valid procedure for spinal analysis.

2. American Medical Association Guides to the Evaluation of Permanent Impairment, 4th Edition, p98 , **1993**.

*Loss of motion segment integrity is defined as an antero-posterior motion or slipping of one vertebra over another greater than 3.5mm for a cervical vertebra...or a difference in the angular motion of two adjacent motion segments greater than 11 degrees in response to spine flexion and extension. From page 109, Table 71. DRE Impairment Category Differentiators*

*...The more objective and important differentiators are marked with an asterisk; the physician should use these to determine the highest impairment category.*

*5.\*Loss of Motion Segment Integrity*

*From page 110,*

*Table 73. DRE Cervicothoracic Spine Impairment categories\* DRE Impairment category IV- Loss of motion segment integrity - 25% impairment of the whole person.*

3. Chiropractic Rehabilitation Course at CMCC, Stanley Kaplan, D.C., Module on the use of the AMA Guides to the Evaluation of Permanent Impairment: **Dr. Kaplan stated to the first class of the Chiropractic Rehabilitation Course at CMCC that there's no point discussing loss of motion segment integrity without a digitizer because you have to measure two films down to 3.5mm which is impossible to do without a computer for the purpose of Impairment rating.**

4. ACCR Guidelines for Diagnostic Imaging and Radiology Practice Parameters.

"The use of radiographic mensuration is sometimes practiced. In these instances, the radiographic analysis may be a component of the clinical examination in the detection of the vertebral subluxation complex. ...The standard of care in diagnostic imaging is that all studies are viewed for interpretation by the practitioner or radiologist to obtain the **maximum level of diagnosis** which is achievable based on the type of study performed."

5. ACCR Position Statement on Computer Assisted Mensuration for Postural Analysis of Radiographs. Presented with 0 references.

***"Computer assisted analysis of radiographs may be useful for the demonstration of roentgenometrics and for the purpose of mensuration as reported in the scientific literature."***

6. Council on Chiropractic Practice, Clinical Practice Guideline, Number 1, Vertebral Subluxation in Chiropractic Practice, p39, 1998. (195 Peer reviewers in 12 countries, approved by the Canadian Chiropractic Awareness Council). ***Radiographic and Other Imaging: ...It is common for lines of mensuration to be drawn on radiographs to assess subluxation and alignment. These procedures may be done by hand, or the chiropractor may utilize computerized radiographic digitization procedures. Rating: Established, Evidence: E, L.***

7. International Chiropractic Association, Recommended Clinical Protocols and Guidelines for the Practice of Chiropractic, August 2000. (over 100 peer reviewers from the United States and Canada). ***...the chiropractor may utilize computerized radiographic digitization procedures. Rating: Established, Evidence: E, L.***

8. Bronfort, G., Jochumsen, O.: The Functional Radiographic Examination of Patients with Low Back Pain; A Study of Different Forms of Variations. JMPT, .7, (2), **1984**. ***Conclusions: "In connection with biplanar studies the roentgenological index points or anatomical landmarks have been marked and digitized and the x, y and z coordinates of these landmarks have been calculated by computer technique."***

9. Coleman, R., Bernard, B., Harrison, D., Harrison, S.: Correlation and Quantification of Projected 2-Dimensional Radiographic Images with Actual 3-Dimensional Y-axis Vertebral Rotations. JMPT 22(1), 1999.

***Materials and Methods: "...the contours were digitized into the computer."***

10. Dvorák, J., Panjabi, M., Grob, D., Novotny, J., Antinnes, J.: Clinical Validation of Functional Flexion/Extension Radiographs of the Cervical Spine. SPINE, 18(1), **1993**.

***Method: "The radiographs were analyzed using a computer assisted method to calculate segmental motion parameters such as rotations, translations and centers of rotation."***

11. Eriksen, K.: Management of Cervical Disc Herniation with Upper Cervical Chiropractic Care. The 15th Annual Upper Cervical Conference, Nov. 21-22, 1998, Life University, Marietta, GA.

***Clinical Features: "These X-rays were read manually (with a template) and with computer-assisted digitization. Computerized analysis also measured misalignments at the levels of L4-L5."***

12. Eriksen, K.: Correction of Juvenile Idiopathic Scoliosis After Primary Upper Cervical Care: A Case Study. CRJ

***X-ray Analysis: "...or computer aided digitization, to measure misalignments of the upper cervical spine."***

13. Frobin, W., Leivseth, G., Biggemann, M., Brinckmann, P.: Sagittal Plane segmental motion of the cervical spine. A new precision measurement protocol and normal motion data of healthy adults. CLINICAL BIOMECHANICS, 17 (2002) 21-31.

***"To summarise, a new protocol for documenting segmental motion of segments C0/C1-C6/C7 is presented and validated. Measurements are based on lateral flexion-extension radiographic views taken in normal clinical settings using computer-aided, objective algorithms."***

14. Harrison, D.E, Cailliet, R., Harrison, D.D., Janik, T., Troyanovich, S., Coleman, R.: Lumbar coupling during lateral translations of the thoracic cage relative to a fixed pelvis. CLINICAL BIOMECHANICS, 14(1999) 704-709.

***"Methods: Three examiners digitized 30 radiographs twice. All interclass coefficients estimates for interobserver and intraobserver reliability were in the range 0.7-1.0."***

15. Harrison, D.E, Harrison, D.D., Cailliet, R., Janik, T., Troyanovich, S.: Cervical

coupling during lateral head translations creates an S-configuration. CLINICAL BIOMECHANICS, 15(2000) 436-440.

***"Methods: Three examiners digitized each of 30 radiographs twice. All interclass coefficients estimates for interobserver and intraobserver reliability were in the range 0.7-1.0."***

16. Harrison, D., Harrison, D., Cailliet, R., Troyanovich, S., Janik, T., Holland, B.: Cobb Method or Harrison Posterior Tangent Method: Which to Choose for Lateral Radiographic Analysis. SPINE, 25(16), 2000.

***Study Design: "Thirty lateral cervical radiographs were digitized twice by three examiners to compare reliability of the Cobb and posterior tangent methods."***

***Conclusion: A reliability analysis of cervical angles generated from radiographic posterior vertebral body angles indicates that the majority of intraclass and interclass correlation coefficients are in the high range...***

17. Harrison, D., Harrison, D., Caillet, R., Janik, T., Jones, W., Cailliet, R., Normand, R.: Comparison of axial and flexural stresses in lordosis and three buckled configurations of the cervical spine. Clinical Biomechanics, 2001

***Design: Digitized measurements from lateral cervical radiographs of four different shapes were used to calculate axial loads and bending moments on the vertebral bodies of C2-C7.***

18. Harrison, D., Harrison, D., Janik, T., Holland, B., Siskin, L., : Slight head extension: does it change the sagittal curve? European Spine Journal, (10) 2001.

***Materials and Methods: Digitized points were used to create posterior body tangent lines on each vertebra...***

19. Harrison, D., Harrison, D., Troyanovich, S.: Reliability of Spinal Displacement Analysis on Plain Films: A Review of Commonly Accepted Facts and Fallacies with Implications for Chiropractic Education and Technique  
***"From the multitude of x-ray reliability studies, which show a good to high degree of inter and intraexaminer reliability, it is obvious that line drawing analysis on plain film radiographs is one of the most investigated topics in the literature."***

20. Harrison, D., Caillet, R., Janik, Troyanovich, S., Holland, B., Harrison, D.: Elliptical Modeling of the Sagittal Lumbar Lordosis and Segmental Rotation

Angles as a Method to Discriminate Between Normal and Low Back Pain Subjects. Journal of Spinal Disorders. Vol11, No.5, pp430-439, **1998**.

***" Lumbar Modeling with an Ellipse: The radiographs were digitized and analyzed using a system composed of a digitizer (GP-9, purchased from Science Accessories Corp., Shelton, CT, USA) and a personal computer. Least Squares Elliptical Modeling: The average least-squares errors, 1-3mm. are approximate to or below the expected inaccuracy of the radiographic measurement, indicating that the lumbar curvature can be indeed be closely approximated with a portion of an ellipse."***

21. Inoue, H., et al: Radiographic Evaluation of the Lumbar Disc Height. Skeletal Radiology. 28:638-643, 1999.

***Materials and Methods: " the points were determined strictly according to the criteria of Quint et al."***

22. Kasai, T., Takaaki, I., Katoh, S., Miyake, R., Tsubo, M.: Growth of the Cervical Spine with Special Reference to Its Lordosis and Mobility. SPINE, 21(18), **1996**.

***Subject and Methods: "The functional lateral radiographs were analyzed using image analyzing software (National Institutes of Health image)..."***

23. Kristjansson, E., Jonsson, H., Is the Sagittal Configuration of the Cervical Spine changed in women with chronic whiplash syndrome? A Comparative Computer-Assisted Radiographic Assessment. JMPT 2002:25:550-5.

***"Setting: Radiography Department at a university hospital. Measurement Technique: The radiographs were scanned into a computer and burned onto CD-ROM discs. A software program, NUDD (Kine Co. Reyjavik, Iceland), was used to mark the desired points on the radiographs. Discussion: In addition, the Harrison posterior tangent method has been found to be more accurately depict cervical curvature than the more commonly applied Cobb method. Therefore, the standing position and the Harrison method are recommended for future studies."***

24. Laney, C.: Field Testing the New Life Cervical Table-Mounted Adjusting Instrument. 16th Annual Upper Cervical Conference, Nov. 20-21, 1999, Life University, Marietta, GA.

***Methods: "The New Life Cervical method of analysis will be employed, and the adjusted using the vector determined by that analysis."***

25. Lind, B., Sihlbom, H., Nordwall, A., Malchau, H.: Normal Range of Motion of the Cervical Spine. Arch Phys Med Rehabil, 70:692-695, **1989**.

***Abstract: "The radiographs were analyzed on a digitizing tablet linked to a computer, using preset points to indicate the motion of the vertebrae."***

26. Nelson, D; Peterson, E; Tilley, B; O'Fallon, W.M.; Chao, E; Riggs, B.L.; and Kleerekoper, M. : Measurement of Vertebral Area on Spine X-rays in Osteoporosis: Reliability of Digitizing Techniques. Journal of Bone and Mineral Research, 5(7), **1990**.

***Abstract: "We conclude that radiographic digitization is a reliable and reproducible method of determining vertebral body dimensions that is suitable for evaluating radiographs obtained at different clinical sites and for comparison with normal data."***

27. Neumann, P., Nordeall, A. et al: Traumatic Instability of the Lumbar Spine; A Dynamic In Vitro Study of the Flexion-Distractoin Injury. SPINE, 20(10), **1995**.

***Methods and Materials: " During the high speed film evaluation, the positions of the balls were determined with an accuracy of +/- 0.1mm by means of a digitizer and an analyzing program."***

28. Osterhouse, M., Tepe,R., Kettner,N., McVey,M., Reliability of the Penning Method for Cervical Intersegmental Motion Assessment: A Pilot Study; Journal of the Neuromusculoskeletal System, Vol. 10, No.2, Summer 2002 p53

***"Computer-assisted evaluation may have the potential for higher reliability, but it requires a computer, software and a film digitizer. This represents a financial burden for the average clinician."***

29. Owens, E.F.,: The Annual Biomechanics Conference on the Spine: A Review of Basic Chiropractic Research at The University of Colorado from 1969-1985. Chiropractic Research Journal, 1(4), **1988**.

30. Owens, E.F., Hoiriis, K.T.: Cervical Curvature Assessment using Digitized Radiographic Analysis. Chiropractic Research Journal, 1(4), **1990**.

***Conclusion: "An x-ray analysis system has been designed which makes use of a sonic digitizer to gather information on the location of radiographic landmarks and computer programs to calculate listings for misalignment."***

31. Owens, E.F., Hosek, R.: Structure Location Errors in an upper Cervical X-

ray Analysis. Chiropractic Research Journal, 1(1), **1988**.

**Conclusion:** *"An x-ray analysis system has been designed which makes use of a sonic digitizer to gather information on the location of radiographic landmarks and computer programs to calculate listings for misalignment."*

32. Panjabi, M., Dvorák, J. et al: Three Dimensional Movement of the Upper Cervical Spine. SPINE, 13(7), 1988.

**Methods:** *"These were digitized to provide geometric relationships between an anatomic coordinate system and the corresponding marker steel balls."*

33. Panjabi, M., Lydon, C. et al: On the Misunderstanding of Clinical Instability. SPINE, 19(23), **1994**.

**Methods:** *"The geometric relationships of the LEDs to the vertebral bodies were established with lateral radiographs. Using specially developed computer programs, relative intervertebral motions in the form of three Euler angles and the translations were calculated at C4-C5, C5-C6, and C6-C7."*

34. Panjabi, M., Chang, D, Dvorák, J.: An Analysis of Errors in kinematic Parameters Associated with in Vivo Functional Radiographs. SPINE, 17(2), **1992**.

**Conclusions:** *"Based on the study of three qualities of lumbar spine functional radiographs, two qualities of digitizers, four spinal levels, and the use of a computer assisted method of kinematic analysis of lateral radiographic views, the following conclusions may be drawn.*

**1.** *Re-digitizing the same radiographic pair results in very small errors ..."*

35. Pettersson, K., Karrholm, J. et al: Decreased Width of the Spinal Canal in Patients With Chronic Symptoms After Whiplash Injury. SPINE, 20(15), **1995**. **Patients and Methods:** *"A graphic digitizer (Digi-Pad; Ortho-Graphic, Inc., Salt Lake City, UT) connected to a microcomputer was used. ... The interobserver variability was within one standard deviation."*

36. Pope, M. and Panjabi, M.: Measurement of the Intervertebral Disc Space Height. SPINE, 2 (4), **1977**.

**Measurement Methods:** *"The measurements of the roentgenographs were made in all cases using a Summagraphics digitizer in conjunction with an Infoton teletype terminal with CRT display, remotely on line with a Xerox Sigma 6 computer."*

37. Provoost, J.: The Vertebral Animator: A window to education and research. 16th Annual Upper Cervical Conference, Nov. 20-21, 1999, Life University, Marietta, GA.

***Discussion: "Perhaps more interesting is the ability for hardware interfacing with new and existing devices such as x-ray scanners/digitizers and ROM measuring devices."***

38. Quint, D., et al: Computer-assisted measurement of lumbar spine radiographs. Acad Radiol **1997**; 4:742-752.

***"Results: Calculations of intra- and interobserver variability for the measurement of spondylolisthesis, disk space height, disk space angle and vertebral body measurements showed that the technique is extremely reliable."***

39. Rajnics, P., Pomero, V., Templier, A., Lavaste, F., Illes, T.: Computer-Assisted Assessment of Spinal Sagittal Plain Radiographs. Journal of Spinal Disorders. Vol. 14, No. 2, pp 135-142 2001

***"These methods are based on the digitization of radiographs and the computerization of the analysis. The results of the evaluation protocol for SpineView software demonstrated that this was a reliable and reproducible measurement method."***

40. Rochester, R., Owens, E.: Patient Placement Error in Rotation and Its Affect on the Upper Cervical Measuring System. CRJ

***Methods: "...measured for each nasium film using a digitizer tablet and computer software."***

41. Rochester, R.: Inter and Intra-examiner Reliability of the Upper Cervical X-ray Marking System: A Third and Expanded Look. CRJ

***Method: The examiners used both manual marking procedures as well as computer assisted analysis using the software program, "THE DOC!" "...It is concluded that all aspects of the upper cervical marking procedures are reliable."***

42. Shaffer, William O., Spratt, Kevin F., Weinstein, James, Lehmann, Thomas R., Goel, Vijay.: The Consistency and Accuracy of Roentgenograms for measuring Sagittal Translation in the Lumbar Motion Segment, An Experimental Model, **1990** Volvo Award in Clinical Sciences.

**"Technique used to measure translation: Several studies have documented the accuracy of biplanar and computer-enhanced techniques in the laboratory and in vivo. However, biplanar techniques suffer from a complexity of measurement requiring computers and a sophisticated knowledge of mathematics that simply reduce their usefulness to the clinician."**

43. Shea, K., Nelson, M., et al: A comparison of manual versus computer assisted radiographic measurement-intraobserver measurement variability for Cobb's Angles. SPINE **1998**;5:531-55.

**Conclusions: "Multicenter studies in which different examiners will be measuring Cobb angles may consider using the computer as a measuring device to reduce intrinsic measurement errors."**

44. Singer, K., Edmonston, S., Day, R., Breidahl, W.,: Computer Assisted Curvature Assessment and Cobb Angle Determination of the Thoracic Kyphosis, An In Vivo and In Vitro Comparison. SPINE, 19 (12), **1994**.  
**Methods: Thoracic kyphosis was measured using the Cobb Method and the mean radius of curvature from computer-assisted digitizing of the vertebral contour."**

45. Singer, K., Jones, T., Breidahl, W.,: A comparison of radiological and computer-assisted measurements of thoracic and thoracolumbar sagittal curve.. Skeletal Radiol **1990**;19:21-6.

**Discussion: "Greater sensitivity with the computerized assessment of thoracolumbar curvature was achieved compared with the Cobb Method...indicates that radiographic evaluation of sagittal spinal curvature is improved with the use of computer-aided measurement."**

46. Smith-Bindman, R., Steiger, P., Cummings, S., Genan, H.,: The Index of Radiographic area (IRA): a new approach to estimating the severity of vertebral deformity. Bone and Mineral, 15 (**1991**) 137-150.

**Methods: "We used a back illuminated digitizing board (GTCO Corporation, Rockville, MD) and a transparent cursor with cross-hairs to register six points for each vertebra from T4 to L4 on an electronic grid that had a resolution of 0.1mm."**

47. Spencer, NE, Steiger, P, Cummings, SR, et al: Placement for points for digitizing the spine. J. Bone Miner Res **1990**;5(suppl2):S247.

**"We conclude that our method is both reliable and reproducible for the placement of points".**

48. Suh, C.: Computer Aided X-ray Analysis and Computer Graphics of the Spine. Third Annual Biomechanics Conference on the Spine, University of Colorado, Nov. 18-19, **1972**.

49. Suh, C.: Displacement Analysis of the Spine with Use of X-rays.. CRJ 1(2), **1988**.

***Abstract : "Given pre and post x-rays of the spine, a computer aided method to compute accurate spinal displacement during the pre and post x-ray period is developed"***

50. Suh, C.: The Fundamentals of Computer Aided X-ray Analysis of the Spine. Journal of Biomechanics, 7(2), **1974**.

***Abstract: "...a step-wise sequential method is developed for accurate x-ray measurement of the spine or other parts of the body for use on the digital computer."***

51. Suh, C.: Minimum Error Point Search for Spinal X-ray Analysis. Chiropractic Research Journal. 1 (1) **1988**.

***Conclusion: " Therefore, the method to eliminate or reduce the human error in reading and analyzing the shadow image of x-rays is improved with use of computers."***

52. Suh, C.: Status Report: Computerized x-ray analysis for the Life Upper-Cervical Adjustment technique..14Th Annual Upper Cervical Conference, Nov. 22-23, **1997**, Life University, Marietta, GA.

***Methods: "This research will focus on the upper-cervical spine and upgrading the Life Upper-Cervical X-ray Technique by developing a new computerized x-ray analysis routine."***

53. Suh, C.: Three-Dimensional Computerized X-ray Analysis of the Upper Cervical Spine: A Progress Report. 16Th Annual Upper Cervical Conference, Nov. 20-21, 1999, Life University, Marietta, GA.

***Results and Conclusions: "This computerized x-ray software and technique which have been developed during the last two years, is based on the following software and techniques published during the last 33 years."***

54. Troyanovich, S., Harrison, D., Harrison, D., Holland, B., Janik, J.: Further Analysis of the Reliability of the Posterior Tangent Lateral Lumbar

Radiographic Mensuration Procedure: Concurrent Validity of Computer-Aided X-Ray Digitization. JMPT, 21 (7), **1998**.

**Conclusion: "Furthermore, the additional data presented here tend to suggest the concurrent validity of the computer-aided digitization method of analysis..."**

55. Troyanovich, S., Harrison, S, Harrison, D., Holland, B., Janik, J. et al: Chiropractic Biophysics Digitized Radiographic Mensuration Analysis of the Anteroposterior Lumbopelvic View: A Reliability Study.. JMPT, 22 (5), 1999.  
**Methods: The digitizing system was composed of a sonic digitizer (GP-9:Science accessories Corporation, Shelton ,Conn.) and an IBM Compatible computer.**  
**Conclusion: Most patient assessment methods used in chiropractic practice have a poor or unknown reliability. The one possible exception to the rule..."**

56. Troyanovich, S., Harrison, D, Harrison, D., Harrison, S., Holland, B., Janik, J. et al: Chiropractic Biophysics Digitized Radiographic Mensuration Analysis of the Anteroposterior Cervicothoracic View: A Reliability Study.. JMPT, 23 (7), 2000.  
**Conclusion: As with other studies investigating the reliability of radiographic mensuration analyses, this study reports a high degree of intraexaminer and interexaminer reliability of the procedure.**

57. Vogt, M., Rubin, D. et al: Lumbar Olisthesis and Lower Back Symptoms in Elderly White Women- The Study of Osteoporosis Fractures. SPINE 23(23), **1998**.  
**Vertebral Measurements: "Films were digitized using a translucent digitizer (GTCO Corporation, Columbia MD) and cursor."**

58. Wiegand, Ray, Wilke,S.: Creating a biomechanical travel card that illustrates the segmental, regional and global organization of the spinal system.. 16th Annual Upper Cervical Conference, Nov. 20-21, 1999, Life University, Marietta, GA.  
**Methods: "We used an electromagnetic grid (9) to record the data points of specific osseous landmarks from a-p and lateral x-rays including cervical flexion and extension views."**

59. Wiegand, Ray, Wilke,S.: Graphical Analysis and Frequency Distribution of Dysfunctional Motion Segments in the Cervical Spine Using Digital X-ray and

database Technologies. 13Th Annual Upper Cervical Conference, Nov. 16-17, 1996, Life University, Marietta, GA.

***Results and Conclusions: "This computerized x-ray software and technique which have been developed during the last two years, is based on the following software and techniques published during the last 33 years."***

60. Wiegand, Ray, Wilke,S.: Quantitative Assessment of form and function of the cervical spine in the sagittal plane. 16th Annual Upper Cervical Conference, Nov. 20-21, 1999, Life University, Marietta, GA.

***Methods: " An electromagnetic grid was used to record the data points of specific osseous landmarks from the neutral, flexion and extension x-ray views."***

61. Williams, S.: Publisher's Corner: Computerized Chiropractic - Technology for the 21st Century. Chiropractic Research Journal, 4(1), **1997.**

***" Computer algorithms will be used to transform digitized information from standard radiographs into true, accurate, three-dimensional coordinates. Using this system, Dr. Suh would like to establish the first "gold standard" for chiropractic biomechanical x-ray analysis."***

62. Yamamoto, I., Panjabi, M. et al: Three Dimensional Movement of the Whole Lumbar Spine and Lumbosacral Joint. SPINE, 14(11), **1989.**

***Materials and methods: " Bilateral oblique and lateral radiographs were taken of the specimen to establish an anatomic coordinate system in each vertebra. These were digitized to provide geometric relationships between the anatomic coordinate system and the corresponding marker."***

63. Yi-Kai, L. et al: Diagnostic Value on Signs of Subluxation of Cervical Vertebrae with radiological Examination. JMPT 22(9), **1998.**

***Statistics: "The data were measured and recorded from the views and were analyzed with BASE statistical software."***

**<http://www.walkfortheunderdog.com/references.html>**

