A Computer System for the Analysis of Dental Casts

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Photographs of Dental casts provide the basis for digitization of major dental landmarks, enabling computerization of such descriptive parameters of occlusion as symmetry, mesiodistal relationships, overbite, overjet, curve of Spee, tooth/arch discrepancies, Bolton ratios, and rotations.

In the practice of orthodontics as well as in the teaching clinic, dental cast analysis is frequently an integral part of the diagnostic work-up and continual treatment monitoring. Over the years, certain standard analyses have evolved, and with the introduction of computer technology into the clinical setting at the University of Illinois Department of Orthodontics, a computerized analysis for the casts was deemed appropriate.

A substantial Fortran computer program has been developed to carry out routine analysis of dental casts for all patients who are treated in the orthodontic clinic. In addition, the program is used in various research studies related to assessing changes in the dentition arising from orthodontic treatment. The program is implemented on an IBM 370 computer. It is presently run in batch mode, whereby a set of punched cards containing the data is submitted to the computer center for subsequent processing. Thus, the user is required only to provide a set of 118 data points from a pair of dental casts. Because the casts are three-dimensional,

photography is used to obtain two-dimensional data for the program.

Photographic Procedure

Prior to photographing the casts, two orientation points on the midline of the maxillary cast are marked with a pencil. These are the dorsal aspect of the incisive papilla and a point on the posterior part of the raphé near the fovea centralis. This establishes the raphé as a reproducible anatomic midline. These points are then transferred to the mandibular cast using a mechanical transfer device described in detail by Hechter.[9] The device (Fig. 1) consists of a hollow metal sleeve that projects upward from a wooden platform to receive an oblong metal post that is free to travel up and down. A horizontal metal rod with a long vertical pin at the end is fitted to the post. The casts are placed on the wooden platform and positioned in such a way that a pin is lined up directly under one of the points on the maxillary cast which is to be transferred. The vertical post is subsequently lowered so that the pin makes a small indentation in the mandibular cast. This depression is then marked with a pencil. The process is then repeated to transfer the remaining point on the midpalatal raphé to the mandibular cast.

The models are photographed utilizing a standardized photographic setup consisting of a 35 mm camera equipped with a 200 mm telephoto lens. This enables the use of a long

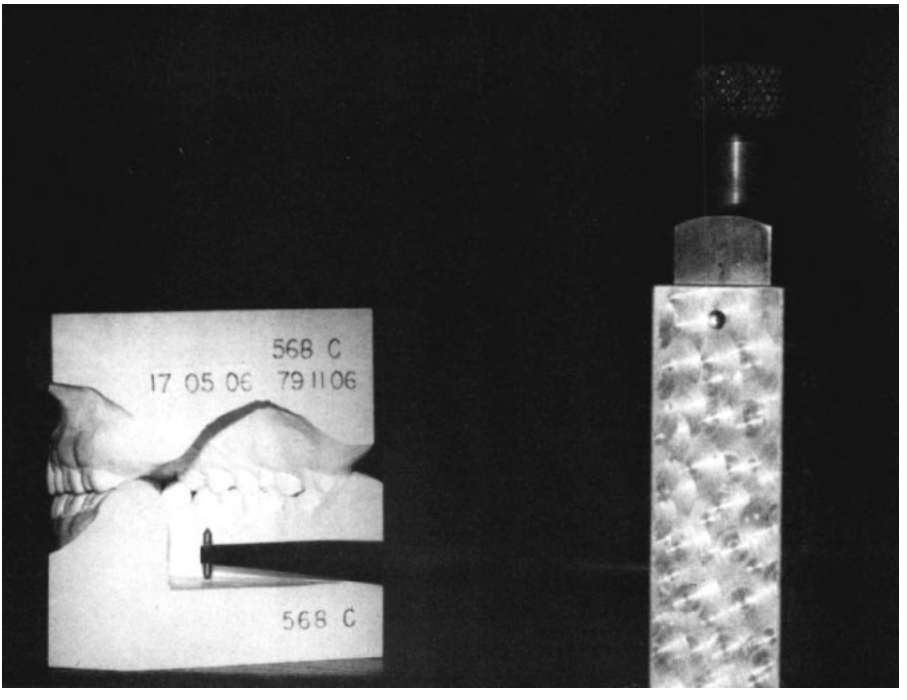

Fig. 1 Mechanical reference point transfer device, showing position of casts.

object-film distance (132.6 cm) to minimize photographic distortion. Five views of each pair of dental models are photographed and, for each view, the occlusal plane is maintained either in a parallel or perpendicular orientation to the film. The views are maxillary and mandibular occlusal, left and right lateral occluded, and right lateral unoccluded, as shown in Figure 2.

Digitizing the Data

After processing, the film strips are projected at about 2× magnification and a set of 118 points, illustrated in Figure 2, is digitized frame-by-frame, using a sonic instrument to record X-Y coordinates of each landmark. This instrument is interfaced to a computer so that coordinates of the landmarks are recorded directly.

Program Description

Since the views of the models as projected are approximately two times larger than life-size, the program first applies a magnification correction factor of 0.4947 to the coordinates so that they correspond to the actual plaster casts. The data are then standardized by rotation along the midpalatal raphé for the maxilla and its analog in the mandible constructed from the transferred points on the lower cast. Computations are then completed and a report printed.

A plotting routine can also provide a graphic display showing lines connecting the most mesial and distal points on individual teeth (Fig. 3). The printed report and plot become a permanent part of the patient's clinic chart. A complete description of the computer program used for the model analysis has been published by BeGole, Cleall, and Gorny.[2]

The program used for these computations utilizes much of the methodology of Cleall and Chebib[6] to process linear distances, projections, and perpendicular distance from a point to a line. In addition, the program is designed to handle as many as five different sets of records for a given patient, and may be used in conjunction with the cephalometric analysis described by Chebib, Cleall, and Carpenter.[5] The records are labeled A for pretreatment, P for progress records, B for the record taken at the end of active treatment, C for the

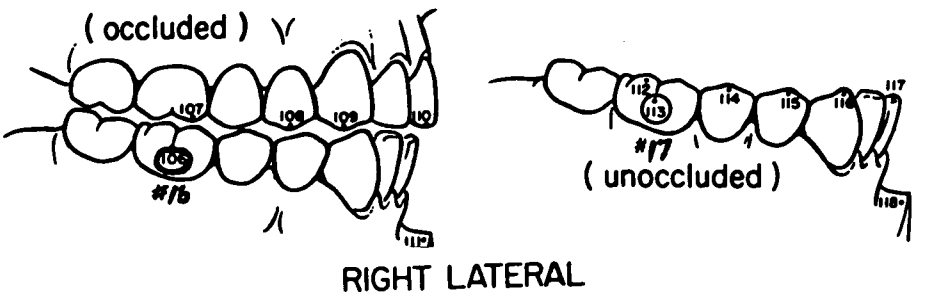

Fig. 2 Standardized views of a set of models showing 118 landmarks to be digitized (101-105 are left-side points comparable to 110-106). *Continued on next page.*

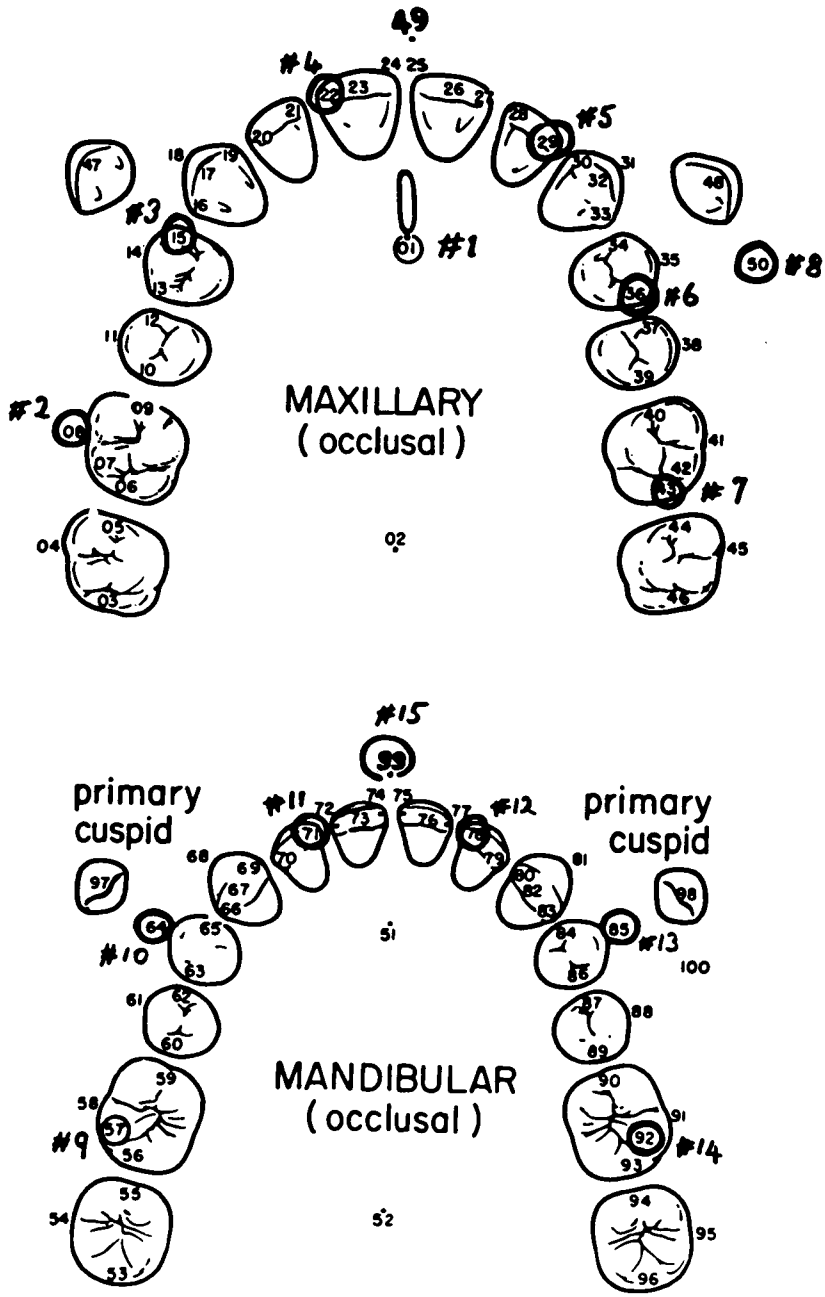

Fig. 2 *Continued*

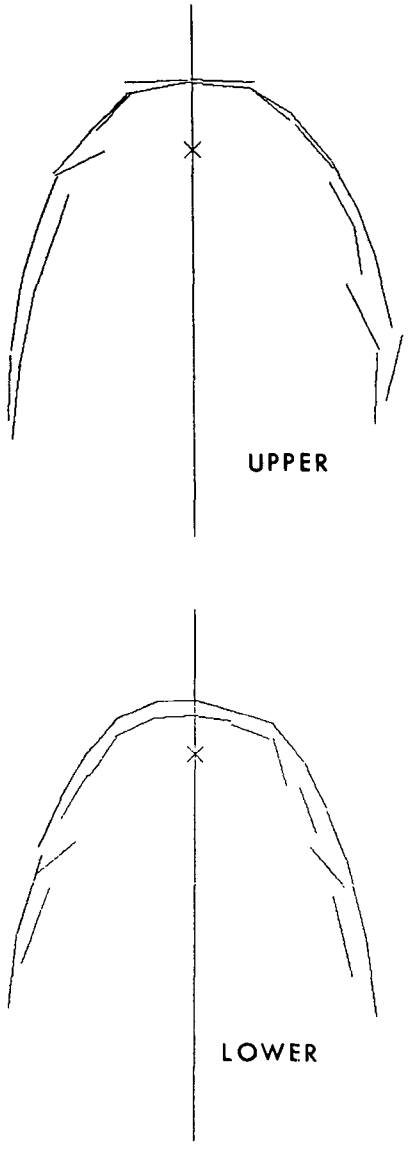

Fig. 3 Plotter output from model analysis program, showing two different records superimposed.

models taken at the end of retention, and D for those taken two or more years postretention.

Printed Report

A sample printed report is shown in table I. In order of the listing, the entries are:

Arch relationship measures the amount of mesial deviation in millimeters of the mesiobuccal cusp of the maxillary first molar from a point representing the buccal groove of the mandibular first molar, as described by Fisk.[7] A class II molar relation is indicated by a positive figure and a Class III relationship by a negative figure.

Overjet, is a measure of the relationship between the maxillary and mandibular central incisor teeth in a horizontal direction as described by Walter.[11] A positive value indicates maxillary overjet, a negative value represents underjet.

Overbite, described by Walter,[11] is used to measure the relationship between the maxillary and mandibular central incisor teeth in a vertical direction. It represents the vertical overlap of the maxillary incisors over the mandibular incisors in mm. A positive value indicates an overbite, a negative value an open bite.

Curve of Spee is measured on the right lateral unoccluded view of the models. The line of occlusion used in the computation is a line connecting the incisal edge of the lower right central incisor to the distobuccal cusp of the lower right first permanent molar. Utilizing the computer routine of Cleall and Chebib,[6] the Curve of Spee is computed as the average of the perpendicular distances to the line of occlusion from the cusp tips of the lower right cuspid and bicuspids.

Compensating Curve is measured on the right lateral view of the upper model. The line of occlusion is formed by connecting the mesiobuccal cusp tip of the upper first permanent molar with a line to the incisal edge of the central incisor. The average of the perpendicular distances to the line of occlusion from the cusp tips of the cuspid and first bicuspid is taken to represent the measurement of compensating curve.

Midlines, utilized by many orthodontists including Walter,[11] is carried out in order to assess deviation of the dental midline from the skeletal midline as determined by the midpalatal raphé in the maxilla or the midline constructed in the mandible by transfer of maxillary landmarks. Midline discrepancy, expressed in millimeters, shows a positive value if the dental deviation is to the left, negative if to the right.

Cuspid Arch Width, suggested by Lundstrom,[10] is expressed as the linear distance between cusp tips of right and left cuspids.

Molar Arch Width expresses the linear distance between distobuccal cusp tips of the first permanent molars.

Arch Length, described in detail by Burke[4] and Hechter,[9] is expressed for both right and left sides, along with the average value for the two sides. It is the distance from the incisal edge of the central incisor to the distobuccal cusp tip of the first molar as measured along the midsagittal plane.

Arch Asymmetry is described by Hechter[9] and is used to provide an indication of overall symmetry of the dental arches. Perpendicular distances from the most buccal or labial point on bicuspids and cuspids are computed to the midline and summed for both right and left sides. The left side total minus the right side total is squared, and the index of symmetry is the squared value. Resulting values of 0-3 suggest a reasonably symmetrical arch form, with larger values indicating asymmetry.

Total dental width is the sum of mesiodistal widths of the teeth lying anterior to the first molars.

Tooth Size/Arch Size analysis is described by many authors, including Fisk[7] and Beazley.[1] The analysis is, in general, based on two measurements, one of which is the total tooth width.

TABLE I

Printed report of a cast analysis. Values (except Bolton ratio) are in mm.

Measure	*A*	*B*
Arch Relationship		
Left	0.4	0.5
Right	2.9	1.5
Overjet	1.3	1.6
Overbite	3.2	0.9
Curve of Spee	0.5	0.1
Compensating Curve	—0.7	—1.1
Midlines		
Maxilla	L 0.7	L 0.2
Mandible	L 0.5	R 1.0
Arch Width Cuspid		
Maxilla	30.6	33.1
Mandible	23.8	25.9
Arch width Molar		
Maxilla	50.3	51.4
Mandible	44.0	45.0
Arch Length Maxilla		
Left	27.9	32.8
Right	26.2	32.0
Mean	27.1	32.4
Arch Length Mandible		
Left	24.0	27.4
Right	25.3	31.0
Mean	24.6	29.2
Arch Asymmetry		
Maxilla	0.0	0.1
Mandible	0.0	0.0
Total Tooth Width		
Maxilla	82.2	87.6
Mandible	75.8	78.6
Arch Size—Tooth Size (Space Available—Tooth Width)		
Maxilla	6.4	6.9
Mandible	—1.5	7.7
Bolton Ratio		
Overall	92.2	89.8
Anterior	76.2	76.1

The second measurement is based on arch perimeter, which is often taken as the sum of various connecting line segments drawn around the dental arch. The analysis, which is the result of subtracting the sum of tooth widths from the perimeter, provides an indication of spacing or crowding of teeth in the dental arch. Perimeter in the analysis used at the University of Illinois is taken as the sum of distances between the mesial surface of the first molar to the distal of the lateral incisor, to the mesial of the central incisor on the opposite side, to the distal of the lateral incisor, to the mesial surface of the first molar. A negative value resulting from the subtraction suggests crowding, whereas a positive value is indicative of spacing of teeth in the dental arch.

Bolton Ratios[3] were devised as a diagnostic aid to gain insight into the functional and esthetic outcome of a case. The anterior ratio gives the percentage relationship of the mandibular anterior tooth widths to the corresponding value for the maxilla. The overall ratio is the percentage relationship of mandibular tooth width for all teeth lying anterior to the second molars to the corresponding maxillary tooth width.

Graphic Display from the Model Analysis

Figure 3 shows a photograph of the plotter output from the model analysis program. The midline with the point of registration marked is shown for both maxilla and mandible, along with straight-line representations of the teeth. For the test subject, two sets of records have been superimposed for the graphics.

The computer system relieves the clinician of carrying out time-consuming hand measurement of dental casts, and is especially useful in universities or clinics where a large number of patients are treated. In using the system, one must keep in mind that a three-dimensional object has been reduced to a set of two-dimensional views through the photographic procedure, much as is done in cephalometrics. A two-dimensional system can never be expected to replace the three-dimensional view of the clinician, but may readily be used to supplement other information the diagnostician draws from the plaster casts and the patient under orthodontic care.

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