G. H. BURGESS*
J. ZULQAR-NAIN
Eastman Dental Center
Rochester, N. Y. 14603

Dental Research Using a Close-Range System

Stereo is used to obtain accurate lineal measurements on the three spatial axes to define the size, shape and location of oral structures.

ABSTRACT: *A short-range stereophotogrammetric system, designed and built by Bausch and Lomb is being used at the Eastman Dental Center to obtain three-dimensional measurements for periodontal research. This paper briefly describes the system, defines the surfaces being measured, outlines the requirements of measurement procedures and discusses three problems encountered in its practical application.*

INTRODUCTION

IN DENTAL research there is a need to obtain accurate measurements for objective quantitation and description of oral structures.[1] A specialized short-range stereophotogrammetric system has been designed and built by Bausch and Lomb within parameters specified by the Eastman Dental Center, Department of Periodontology. This system is used to obtain three dimensional measurement data for clinical research projects.

DESCRIPTION OF SYSTEM

The system design is based on the principles of a projected analogic stereomodel. It consists of an acquisition component to obtain the stereophotographs and an evaluation component to obtain measurement data.[2]

ACQUISITION COMPONENT

A pair of Honeywell Pentax H-1-A,† 35-mm. cameras were altered by the addition of special Baltar lenses. Fiducial marks, ground into the focal plane frame, appear on the negatives and define the principal point. Estar base film‡ specially cut and perforated, provides dimensionally stable negatives. The cameras are held in a fixed relationship in a cradle. The cradle is placed on a special mount which allows the cameras to be leveled, aligned and accurately focused on the surface to be photographed. Simultaneous exposure is achieved by use of a split cable release. A pair of Braun electronic flashes,+ mounted on the cradle, are synchronized to the shutters to provide lighting.

The convergent case of photogrammetry is used and the optical axes intersect at the external conjugate of the fixed focus lenses forming an isosceles triangle of known properties. The use of convergent photography allows greater access into the restricted areas of the mouth and provides more accurate *Z*-axis determinations.[3]

EVALUATION COMPONENT

The acquisition cameras are designed to be compatible with the projectors of the 760

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† Honeywell Photographic, Denver, Colo.

‡ Kodak Recordak Special Micro-File AHU Film Type SO-291.

+ Braun Div., Ehrenreich Photo-Optical Ind., Inc., Garden City, N. Y.

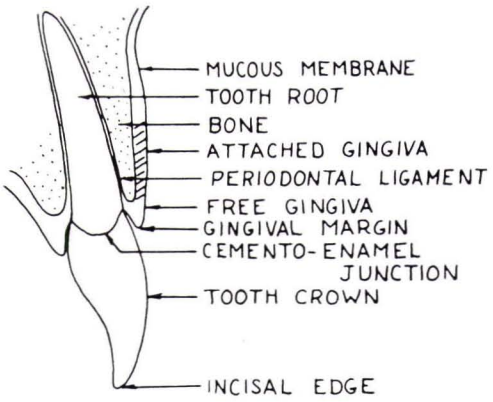

FIG. 1. Schematic of a sagittal section through an upper incisor showing the location of dental structures.

Balplex Plotter.* The system design also allows the negatives to be printed at 1:1 on Aerographic Positive Plates.**

The angular relationships of the isosceles triangle formed by the acquisition system is duplicated by the projectors of the Balplex. The base separation of the projectors is four times that of the cameras and the resulting stereomodel image is four times the size of the natural object. A metric tracing table is geared to read Z values direct to the nearest 0.02 mm. at object or natural size.

DESCRIPTION OF SURFACES BEING MEASURED

The areas being measured are the exterior (labial) surface of the upper and lower anterior teeth and gums or gingivae. Features of interest are the incisal edge and crown of the teeth, the gingival margin, the free gingiva, the gingiva attached to the underlying bone by connective tissue and the cemento-enamel junction (Figure 1).

The crowns of the teeth have grooves and lines which provide photographic contrast. The gingival tissue is textured and the attached gingiva has areas of small indentations, called stippling, which gives an orange peel appearance, adding to the photographic contrast of the gingival tissue surface.

MEASUREMENT PROCEDURES

In periodontal research, horizontal and longitudinal studies are conducted of normal and abnormal conditions. Longitudinal studies may vary in time from a few weeks to several years. Changes to be measured range from the subtle effects of age to the gross effects of surgery.

Oral structures are three-dimensional objects. To define their shape, size and location properly at any given time or over a period of time, measurements must be made along the three spatial axes. In a horizontal study, standard methods of establishing reference lines and points must be employed to provide correlated measurement data. To follow an individual through a period of time, the measurements must be related to an arbitrary datum which can be recovered in successive models.

The measurements obtained must be of significant accuracy for clinical studies of surface shapes. A standard error of ± 0.10 mm. at natural size was specified for the system. The time imposed on the subject and the physical inconvenience must also be minimal.

PRACTICAL APPLICATION OF THE SYSTEM

Several problems encountered during the clinical application of this system and their solutions are discussed.

NEGATIVE AND MODEL QUALITY

To obtain reliable measurement data from the evaluation component it is desirable to have stereoscopic models of good quality. This is facilitated by obtaining good negatives and following proper diapositive printing procedures. Examination of negatives by visual means and by use of a Kodak No. 1 Densitometer†[4] revealed variations in quality, absolute density and density scale. These variations occurred between subjects, within one subject at various time intervals and between the two cameras for simultaneous exposures.

Negative handling procedure was standardized. To allow for the stabilization of the latent image on the film, a 20-hour lapse be-

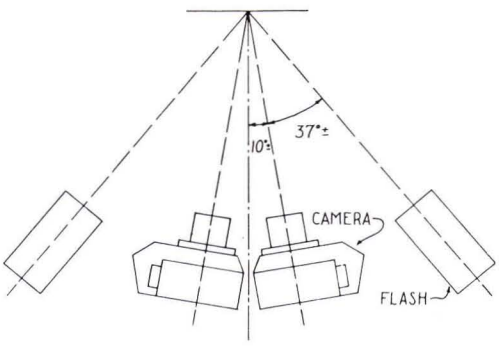

FIG. 2. Top view schematic showing relationship of flash units to the cameras for photography of the anterior teeth and gingivae.

* Bausch and Lomb, Inc., Rochester, N. Y.
** Eastman Kodak Co., Rochester, N. Y.

tween exposure and processing was required. The negatives were developed in a Nikor tank using Kodak HC-110, Solution B,† for 7 minutes at 20° C and fixed in a normal manner.

A simple experiment was conducted which indicated that the electronic flash synchronization and light intensity output was very consistent. Therefore, these two factors were eliminated as a cause of negative differences.

A series of exposures were made varying the position and angulation of the flash units. This determined that a maximum amount of detail appeared on the negatives when the units were positioned on the same level as and slightly behind the camera lenses. They were pointed to the convergent point of the cameras and formed angles of about 37° to the optical axes (Figure 2). The lens aperture was varied until negatives of a desired density were obtained. The density scale between the teeth and gums was determined with a densitometer. Normal or contrast plates were used with the recommended developer to obtain a predetermined density scale.[5] These tests and the resulting standardization provided negatives and stereomodels of good quality and consistency.

REFERENCE FRAMES

In order to superimpose successive models of the same subject it is necessary to establish a vertical and a horizontal datum for absolute orientation. This can be done by providing a suitable reference frame in the mouth at the time of photography. Attempts to provide such a frame include the identification of natural marks of the teeth surface at various time intervals, setting of targets in small holes drilled into the teeth before the initial photography, anterior acrylic bites with inlayed steel wires and gold onlays with attached steel crosses placed on the bicuspids at the time of photography. For a study covering a three-month period a pair of orthodontic bands were cemented to the first bicuspids.[6] A solid steel wire, fitted to the tubes, was inserted at the time of photography. The outline of the wire was drawn on the plan view in the initial model and provided the horizontal datum. Elevations were read on the surface of the wire to relevel successive models. All these attempts were unsatisfactory as they either did not provide the desired accuracy or were too great an imposition upon the subject.

A posterior bite formed from quick-set acrylic on a plexiglass base has been developed (Figure 3). The plexiglass is cut to fit the individual mouth. The subject bites into the acrylic, which is molded around the sides of the base, embedding his molars. The acrylic sets in a few minutes and the subject is free to leave. Wire targets are added to the bite at a later time, positioned according to the area of interest. Preliminary test results indicate that this bite will fulfill the requirements of a suitable reference frame.

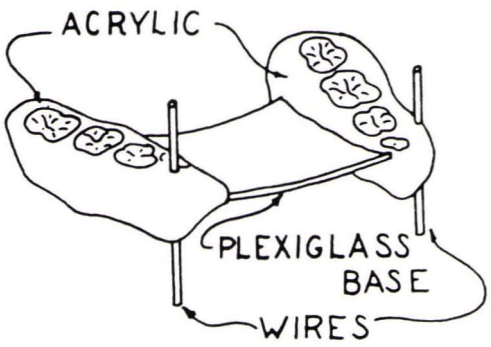

FIG. 3. Posterior bite formed in the mouth from acrylic on a plexiglass base with wire reference frame for anterior photography.

DATA PRESENTATION

Various attempts were made to present measurement data obtained from the system in a form meaningful to the researcher. Contour maps, volume determination by the *borrow pit* method[7] and digitizing of surface shape and location were tried.

A plan view drawing of the exterior (labial) surface of the upper and lower anterior teeth and gums was made (Figure 4). The tips of the wire targets were outlined on the drawing for reorientation of successive models. An arbitrary grid intersection of $Y = 200$ mm., $X = 100$ mm. was held at the upper left corner of tip No. 1 and the direction (azimuth) of the grid system was determined by a line from tip No. 1 to tip No. 2 (Figure 4). Z-axis values were recorded near the four tips to provide the vertical datum for absolute reorientation. Lines such a A—A and B—B were selected along which a sufficient number of elevations were read and recorded to define the surface shape. These values, using an arbitrary line as a base for offset distances were plotted on graph paper forming sagittal sections at ten times natural size (Figure 5).

These diagrams show that the size, shape and location of oral structures can be objectively quantitated by measurements related

† Eastman Kodak Co., Rochester, N. Y.

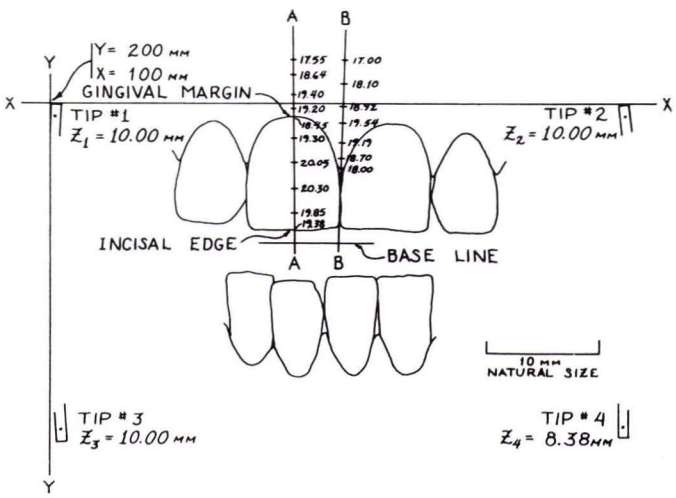

FIG. 4. Plan view drawing showing upper and lower anterior teeth and gingivae, wire reference frame tips (1–4), arbitrary grid ($Y-Y$, $X-X$), vertical datum values (Z_1-Z_4) and selected sagittal section lines ($A-A$, $B-B$) with elevation readings recorded.

to the grid system and/or to the vertical datum. Similar data can be obtained from successive models of a subject to show changes over a period of time. For present studies this is a meaningful method of data presentation.

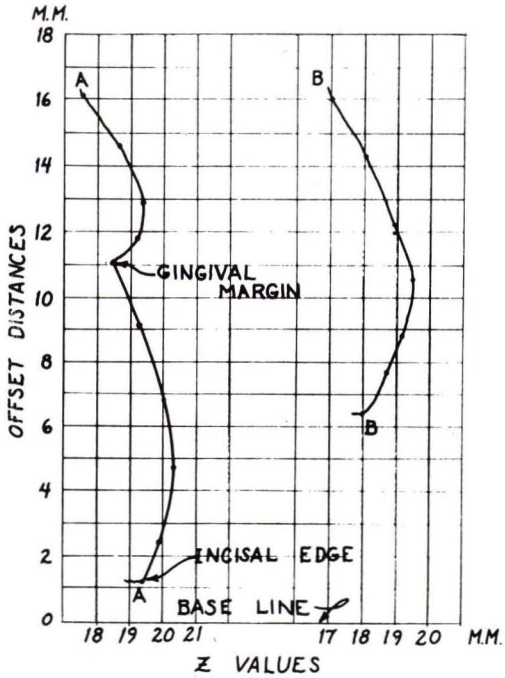

FIG. 5. Sagittal sections plotted on graph paper at ten times natural size. Grid squares represent 1 mm.×1 mm. at natural size.

SUMMARY

A stereophotogrammetric system is being used to obtain accurate lineal measurements on the three spatial axes to define the size, shape and location of oral structures for dental research. Photographs are obtained by a pair of special 35-mm. cameras mounted in a convergent relationship. The stereomodels are evaluated in a standard 760 Balplex plotter. A replaceable reference frame is used to reorient successive models of a subject to the same horizontal and vertical datum. Problems such as model quality, suitable reference frame and data presentation encountered in the practical application of the system have been solved in a logical manner.

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