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The Computer and the Law: Coordinate Analysis of Skull Shape and Possible Methods of Postmortem Identification

After death, the human body usually disintegrates quite rapidly. The rate of disintegration depends mainly on the temperature and humidity to which the body is exposed. Under extremely cold conditions the process of cell digestion or proteolysis is virtually halted, and bodies found in glaciers or arctic conditions can often be identified many years later.

If postmortem conditions are hot but extremely dry, the body undergoes dessication or drying out until the soft tissues such as skin, muscles, and internal organs become like leather in appearance and are usually hard and relatively brittle. Bodies buried in hot sand, a custom carried out in Egypt for many centuries, causes the subject to become mummified in three to four weeks, and if the burial is carefully done, it preserves the general appearance remarkably well. In examples such as these, postmortem identification presents no particular problems.

In police work it is more common to find a body on which the soft tissues are either partially or completely absent, thus making the identification of the subject extremely difficult. On such occasions it is usual to try to establish the sex, age, and ethnic background of the individual and thus narrow the search for missing persons. As would be expected, articles found with the body such as clothing, jewelry, or a wallet or purse may often lead to a more rapid identification.

Under some circumstances, where the body has been exposed to the elements for a comparatively long period such as in cases of drowning or a shallow or open grave, little but the bones may be left, and identification becomes increasingly difficult.

Under these conditions X-ray investigations of the skull, assisted by information from a large computer-based data bank of other skeletal material, can provide statistical information related to the probable age, sex, race, and facial appearance of the subject.

From X-ray studies of the bone structure and facial profile of many thousands of individuals, the Biometrics Laboratory has been able to establish the average size and shape of the skull and facial bones of individuals from childhood to old age. Similarly, we have measured the thickness of the soft tissues over the face and have developed statistical and predictive methods to provide the "most probable" profile, based on measurements of the facial bones.

The present method of measuring the facial bones and soft tissue profile requires the conversion or translation of the anatomical landmarks and contours to X-Y coordinates as has been described elsewhere [*1-3*]. Figure 1 indicates the outlines of the craniofacial

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FIG. 1—*The outlines of the craniofacial bones.*

bones and Fig. 2, the set of coordinates which are used in recording the size, shape, and position of these parts.

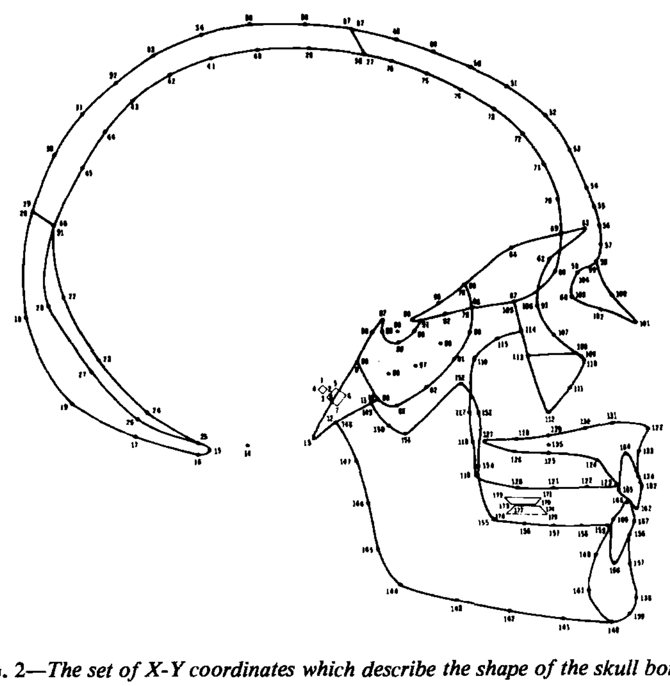

FIG. 2—*The set of X-Y coordinates which describe the shape of the skull bones.*

Using this method it is possible to store and retrieve many thousands of skull and facial patterns from a data bank. Figure 3 shows computer plots of a series of black veterans and

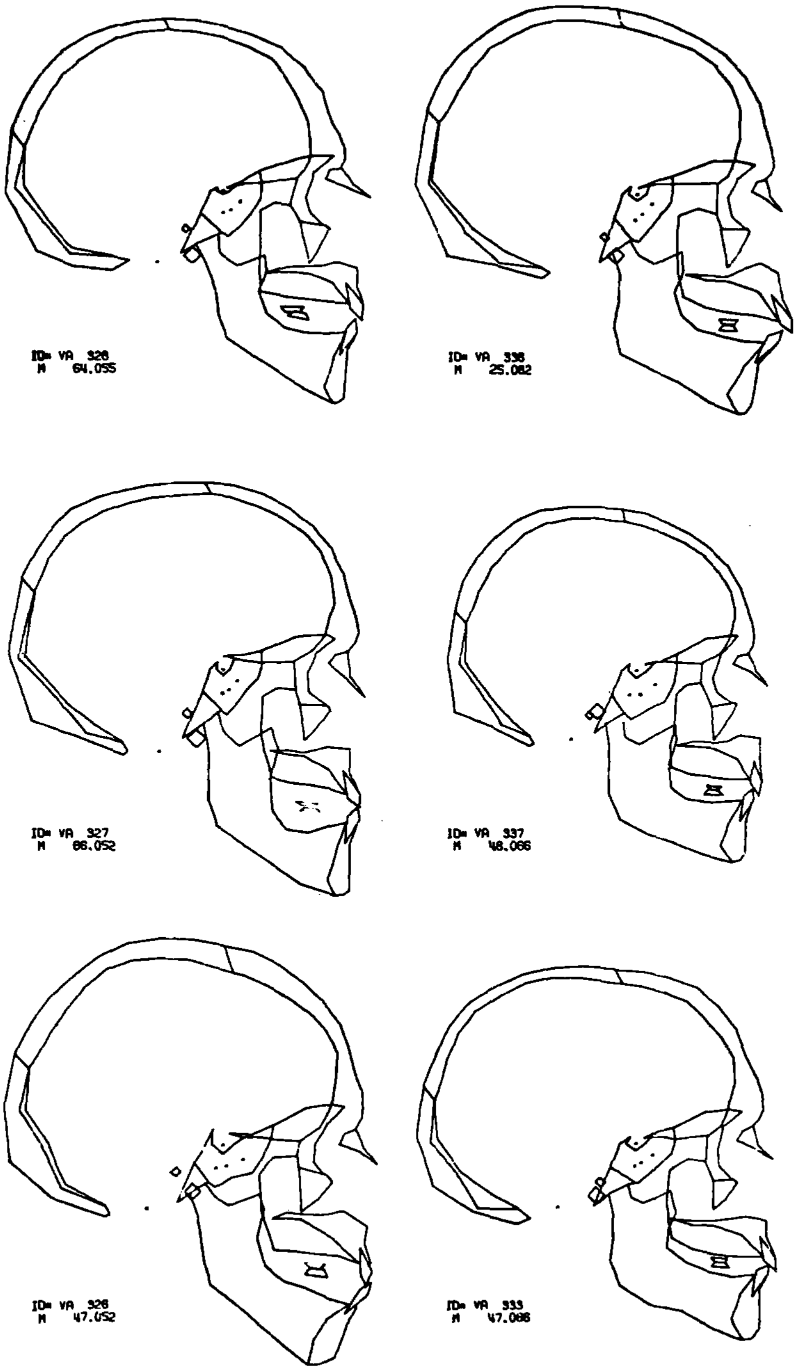

FIG. 3—*Skulls of black veterans.*

Fig. 4, a series of white veterans. Using suitable programs it is possible to compute many skull and facial measurements and by comparing these with the statistical information in the data banks we may then establish age, sex, and racial origin [4] within reasonable ranges of probability.

Up to 25 years of age, the teeth provide fairly accurate indicators of maturational level.

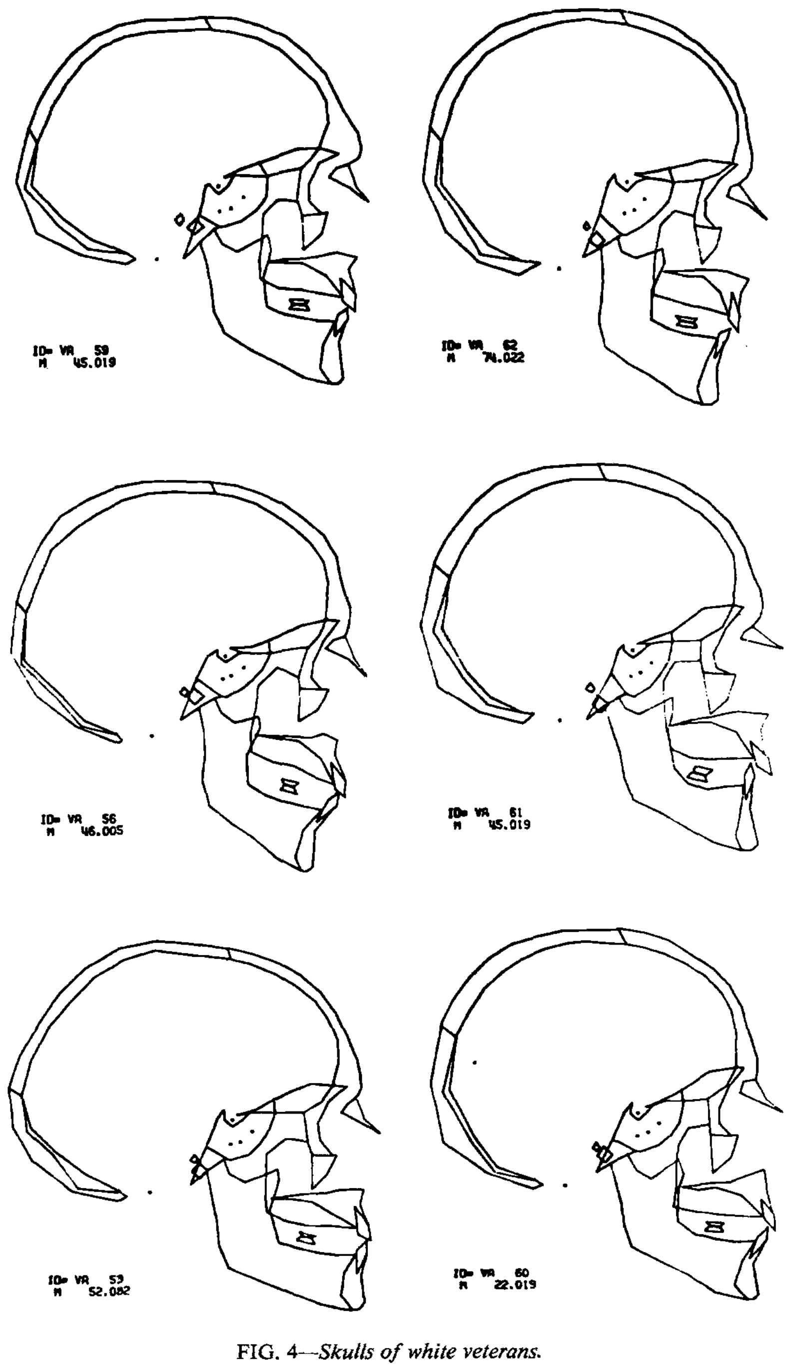

FIG. 4—*Skulls of white veterans.*

Beyond that age, estimates become less precise, and the fusion of sutures together with the wear of the dentition are some of the available guidelines. The size and shape of the facial bones, together with the robustness of the skull and muscle attachments can usually lead to a reliable identification of sex in some 70% to 80% of cases.

Racial or ethnic origin is often more difficult to assess, particularly if the subject is of mixed descent. For example, some of the skull patterns in our data banks are unmistakably black (95% probability), as in Fig. 5, or white (90% probability), as in Fig. 6. Figure 7 is a subject of mixed origin and has been classified as black, but at only a 55% probability.

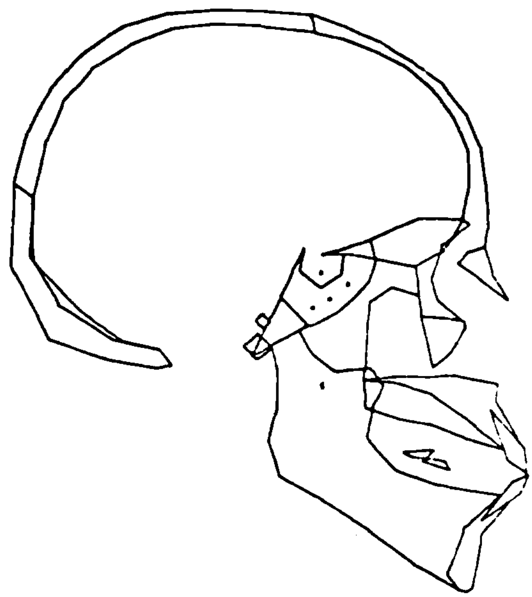

FIG. 5—*Black skull, 95% probability.*

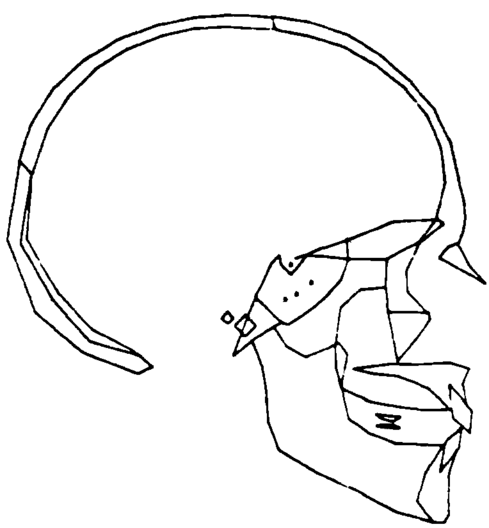

FIG. 6—*White skull, 90% probability.*

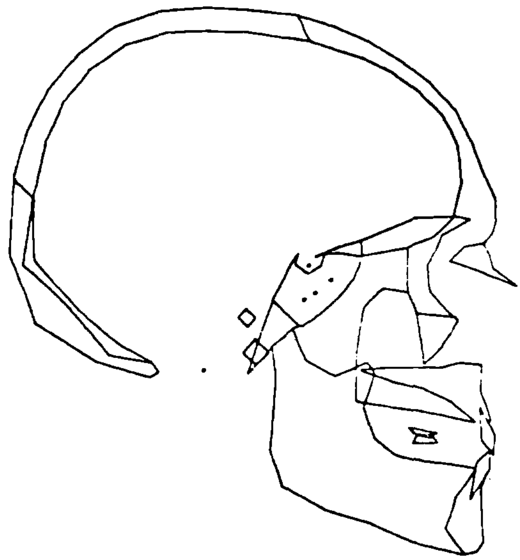

FIG. 7—*Black skull, 55% probability.*

In a similar way we have recorded the facial contours and profiles of many hundreds of individuals. Figure 8 shows a group of blacks and Fig. 9, a group of whites.

From this data bank we have computed the range of skin and soft tissue thicknesses over the forehead and the upper and lower face. Using these data we may reconstruct the most probable profile for a particular skull. As may be seen from the previous figures, the nose and lips show the greatest variation. Hence the average measurements may be modified and improved by using prediction equations derived from statistical regression studies.

One of our experiments was to derive composites or averages of the facial profiles at ages 20 to 30, 30 to 40, and 40 to 50. Striking differences between the black and white veterans became apparent, and these were supported by statistical analysis. The average profile of the blacks did not change significantly from the twenties to the fifties, as is shown in Fig. 10, and a similarly unchanging pattern was noticed in the white veterans, as shown in Fig. 11.

When a series of measurements were made horizontally from the bony outlines to the skin at the profile, quite significant differences were noted (Table 1).

Thus both the bridge and the length of the nose are less prominent in blacks. In contrast the lips tend to be thicker, especially the lower. It would seem, however, that the thickness of the upper lip is not significantly different as is shown by Measurement 6 in Table 1.

TABLE 1—*Horizontal measurements, in mm, from the bony outlines to the skin at the profile.*

Measurement	Blacks		Whites		Significant p values
	Average	SD	Average	SD	
Nasion	6.33	±1.70	7.40	±2.23	<0.01
Orbit to nasal bridge	25.67	±3.90	30.48	±4.06	<0.0001
Orbit to nose tip	47.36	±3.35	50.17	±3.34	<0.001
Nasal spine to nose tip	29.47	±3.88	33.59	±2.81	<0.0001
Lower incisor to lower lip	17.70	±2.13	16.70	±1.93	<0.02
Upper incisor to upper lip	16.12	±2.80	15.59	±2.90	>0.36

SD = standard deviation

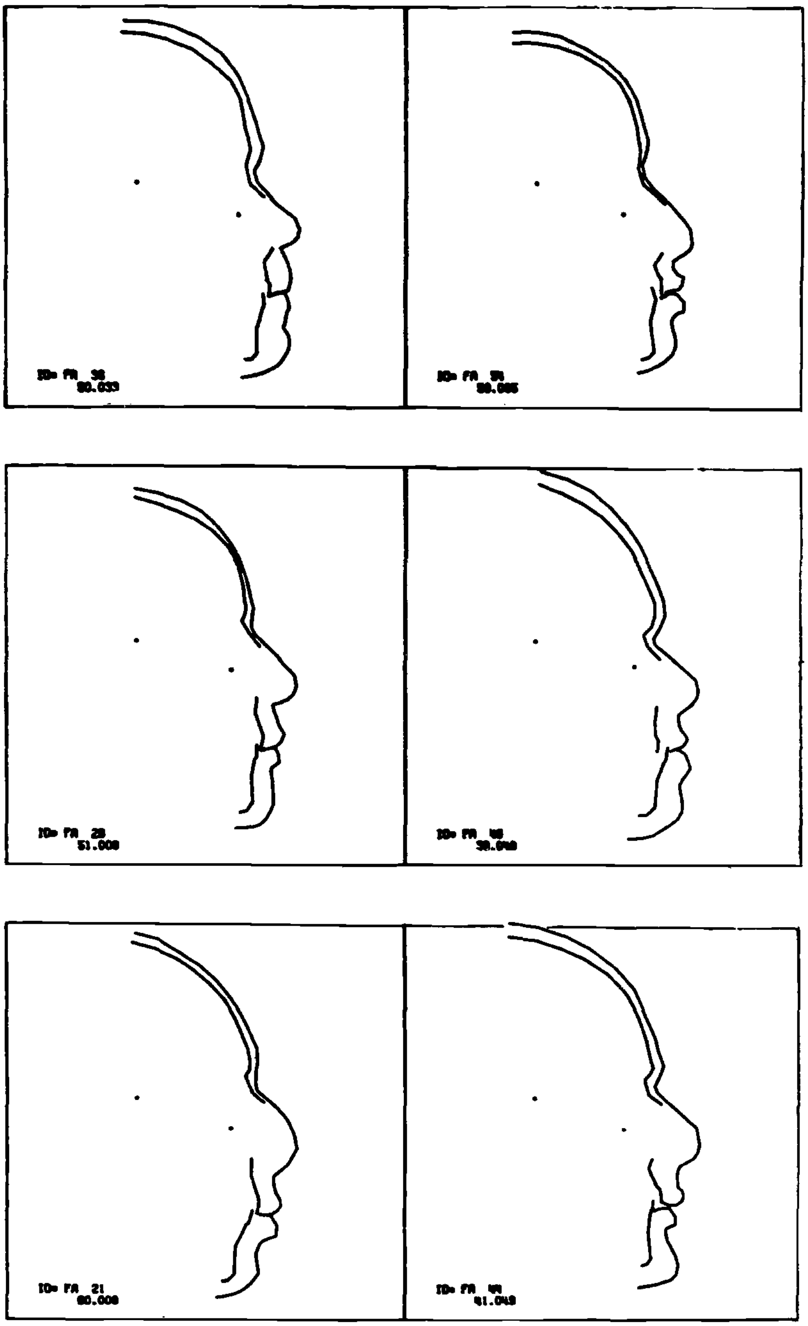

FIG. 8—*Profiles of black veterans.*

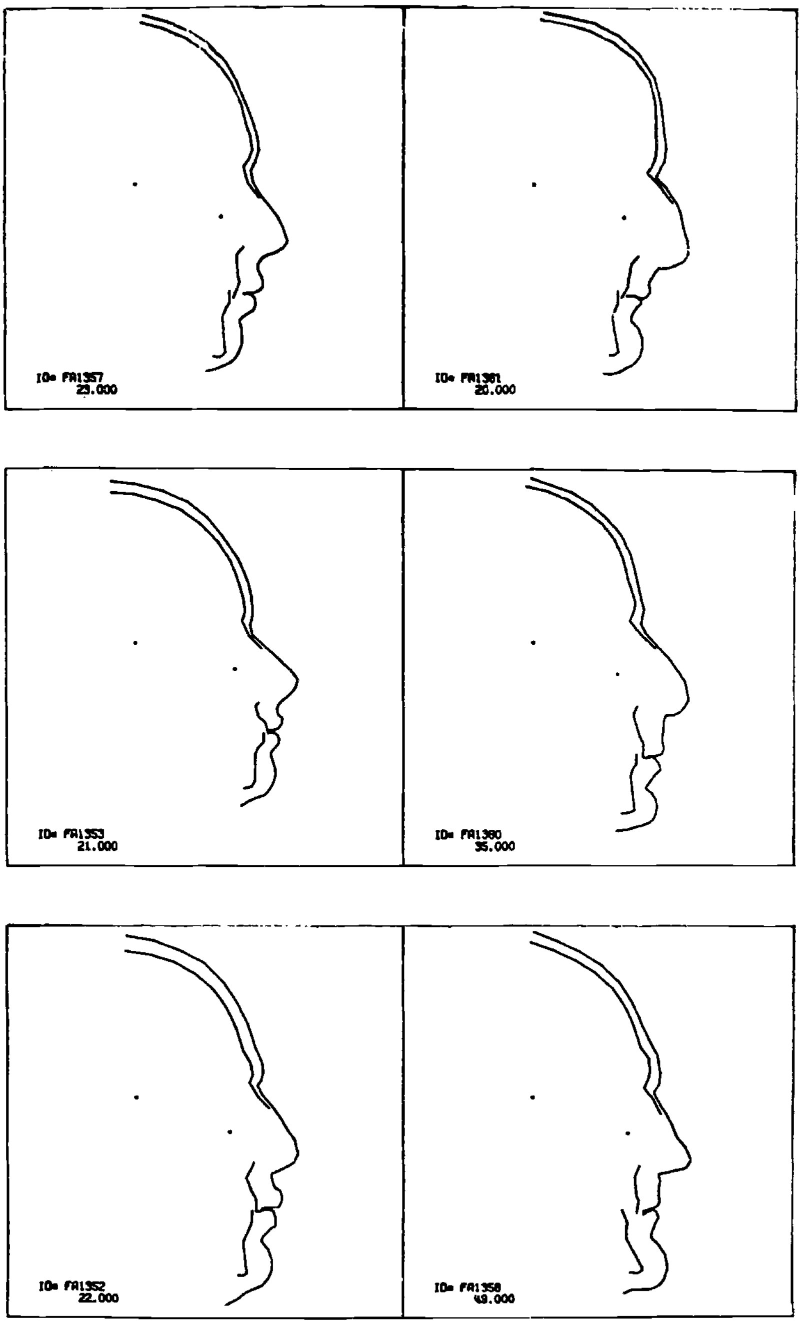

FIG. 9—*Profiles of white veterans.*

From Figs. 10 and 11 it becomes apparent that the black profile has relatively prominent jaws and dentition and that these have a high correlation with the soft tissues. These features have been used to derive prediction equations which may be used to compute more precise estimates of the profile outlines of the missing parts.

In a similar manner, measurements of the degree of prominence of the bony landmarks may be used as input to a discriminant analysis to estimate the racial origin of the skull being examined.

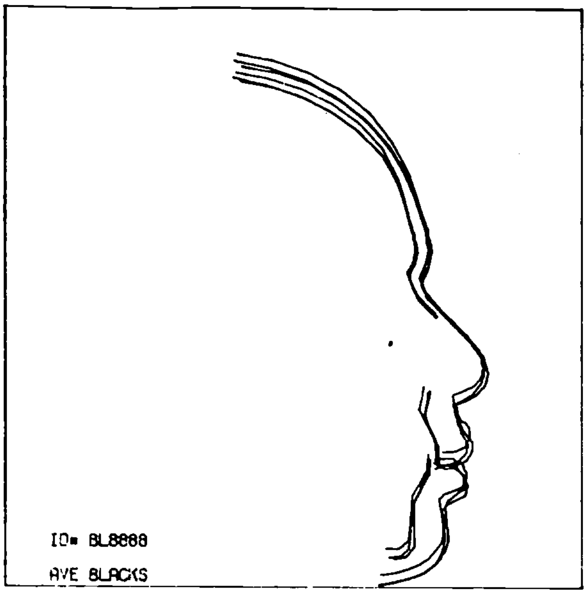

FIG. 10—*Average profiles for black veterans, ages 20, 30, and 40 years.*

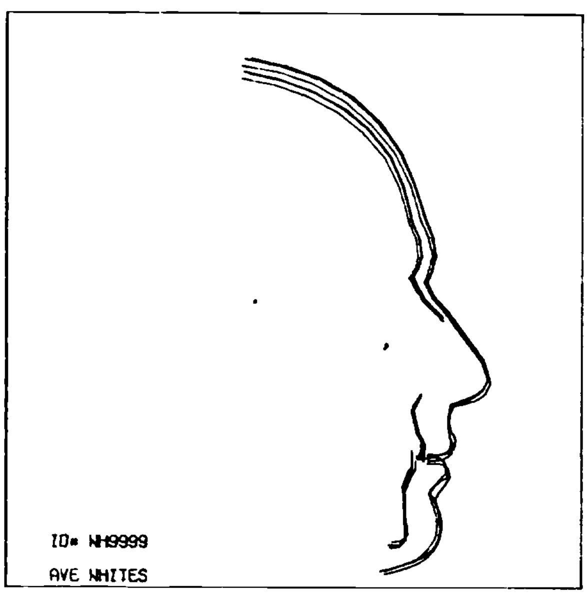

FIG. 11—*Average profiles for white veterans, ages 20, 30, and 40 years.*

Summary

Mechanisms accelerating or retarding the disintegration of soft tissues are briefly discussed, as well as the need to reconstruct the missing profile for postmortem identification purposes.

The application of X-ray and computer-based analyses is discussed in the context of providing data to predict and reconstruct the most probable soft tissue profile of a dry skull.

In addition, information from extensive studies of the facial bones and profiles of veterans has been applied to methods in forensic medicine of determining age, sex, and racial background of unknown subjects.

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