GROWTH RETARDATION AND VOLUME DETERMINATIONS OF THE ANOPHTHALMIC ORBIT*

BY *Robert E. Kennedy*, MD

IN RECENT YEARS A DEFINITE PATTERN HAS DEVELOPED TO SHOW THE RELAtionship between congenital and acquired anophthalmos and the growth of the orbital bones. Changes in size of the anophthalmic orbit in the human were determined by linear measurements from roentgenographic studies only, but this does not allow a determination of orbital volume. While volumetric studies of the normal orbit have been made, the lack of availability of specimens has prevented any direct volumetric measurements of the abnormal anophthalmic orbit. Such direct measurements would be worthwhile to provide more information for better management of the clinical problems of the anophthalmic orbit.

The recent acquisition of two interesting skulls permits volumetric determinations of a skull with abnormal orbits and a skull with one anophthalmic orbit.

Linear measurements of the anophthalmic orbit had been made in the rabbit and cat from roentgen and bony skull measurements, and in the human by roentgen measurements only.[1]

Orbital size has been studied in the rabbit after early enucleation by Thomson[2] and by Kennedy.[1] These linear measurements showed a decrease in the anophthalmic orbit in the magnitude of 12.6 per cent. Volume determinations in the normal rabbit have been made by Schultz[3] and by the imprint method by Sarnat.[4,9]

The cat skull, studied extensively in 1964, showed marked changes which are of interest.[1] The linear measurements of the anophthalmic orbit, as compared to the normal orbit, showed a decrease of approximately 27 per cent in the magnitude of the orbital entrance. The characteristic bone changes showed a smaller orbital entrance and a narrowed

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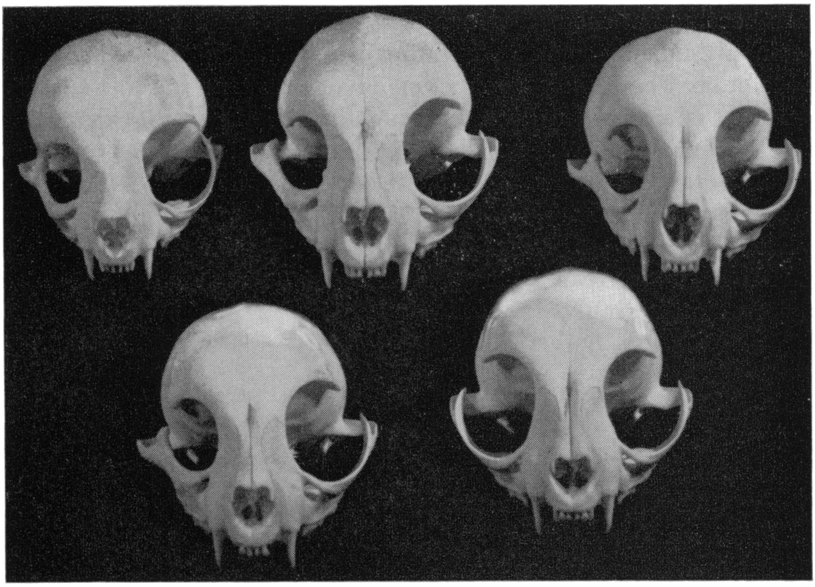

FIGURE 1
The skulls of a litter of five cats. Four cats have had the right eyes enucleated, showing characteristic changes which can be produced regularly. The lower right skull is the unoperated control (operated on day 15, sacrificed day 116).

gap between the frontal and zygomatic processes, as shown in Figure 1. The sharp rim edges were more rounded and smooth, and the bone appeared porous and less dense. The optic canal was smaller. The orbital depth was decreased by 11.5 per cent. The cat skull, which lacks an orbital floor, does not lend itself readily to volumetric determinations by the usual methods.

Cephalometric determinations in the human depend on roentgenograms. Following enucleations in infancy and childhood the anophthalmic orbit is definitely smaller than the orbit of the normal side. The earlier the enucleation, the greater is the magnitude of change. The change is less when an orbital implant has been inserted. The decrease in the orbital measurements is up to 8 per cent when an implant is used, and up to 15 per cent when no implant has been inserted.[1]

The volume of the orbit in the normal human skull is about 30 cc. Retarded development after early enucleation results in a decrease in the orbital volume which can be appreciated by roentgen examination. This is manifested by a decrease in orbital entrance measurements, and contracture and irregularity of the orbital walls. The normally concave walls become flattened or even convex. The roof of the orbit tends to flatten, presumably as a manifestation of pulsations of the frontal lobe of the brain. The maxillary and ethmoid air cells tend to show enlargement and encroachment into the anophthalmic orbit. With decreased orbital volume contraction of the temporalis muscle may influence the lateral orbital wall to encroach into the anophthalmic orbit. Facial asymmetry may be manifested by a decrease from the midline to the lateral wall of the orbit on the involved side. The optic canals are usually smaller. A greater realization of these changes can result from stereoscopic projections and study of the orbit.

MATERIALS AND METHODS

The orbital volume of the following skulls were determined:

1 Normal skull
2 Broken Hill (Rhodesian Man) skull
3 American Indian skulls
4 Skull with bilateral constricted orbital rims
5 Skull with normal right, constricted left, orbit

Linear measurements of the orbits were made according to the procedure previously outlined by Kennedy.[1]

The orbital volumes of the skulls to be studied were determined by a sand technique and an imprint method. The latter seemed more satisfactory with minimal threat to damaging the skulls. The imprint method has been used to determine the normal orbital volume in the rabbit at various growth stages with good correlation.[4]

A light-bodied elastic rubber-base imprint material (Permlastic-Kerr) was prepared by mixing for approximately one minute equal parts of the base material and the catalyst. A rubber condom partially filled with the imprint material was introduced into the orbital cavity and pressed into position. An attempt was made to have sufficient imprint material in the orbit to allow as nearly as possible a vertical flat plane curved nasally to temporally, following the contour of the orbital entrance of each orbit of the four skulls studied. The imprint material was allowed to set at room temperature; because of its elasticity it could be easily removed without damage to the imprint or the anatomic specimen. Any excess at the anterior surface of the orbital entrance was trimmed with scissors before removing the imprint. From the net weight and specific gravity of the imprints the orbital volumes were determined. The average of three imprints of each orbit was taken.

FIGURE 2
Normal skull on the left. Replication of Broken Hill (Rhodesian Man) skull, approximately 50,000 years old, showing enormous face, high prominent brow ridges, large orbits with irregular contour of rims, on the right.

TABLE 1 ORBITAL MEASUREMENTS

	Height (mm)	Width (mm)	Diagonal UN – LT (mm)	Diagonal LN – UT (mm)	Orbital volume (cc)
Normal skull	33	40	41.2	36	30
Broken Hill (Rhodesian Man) skull	39	45	48.5	50.5	44

UN (upper nasal), LT (lower temporal), LN (lower nasal), UT (upper temporal).

EXAMINATION OF SKULLS

1. BROKEN HILL (RHODESIAN MAN) SKULL

Of anthropological interest is the study of the Broken Hill (Rhodesian Man) skull (Figure 2), using a replication of this skull (made available for study through the Wenner-Gren Anthropological Foundation Inc.) which dates back to the Neanderthal age, some 50,000 years ago. One can see an enormous face, high brow ridges, large orbits with an irregular contour, and a large orbital volume. Table 1 compares the orbital entrance measurements with those of a normal skull.

Table 1 shows that, when the differences in the readings are averaged, the orbit of the Rhodesian Man skull is larger than the normal orbit of a modern skull by about 22.2 per cent, or the present-day skull to be almost 17.6 per cent smaller than the Broken Hill (Rhodesian Man) skull. The orbital volume of the Rhodesian Man skull measured about 50 per cent larger than the normal skull of today. Like the automobile in their changes, orbits seem to have become more streamlined, rounded, and smaller in proportion to the face.

2. AMERICAN INDIAN SKULLS

Three Indian skulls found in New York State, and estimated to be six thousand years old, revealed measurements with no significant variations from the average skull of today. These skulls (made available for study through the Rochester Museum and Science Center) were studied only by linear measurement.

3. SKULL WITH BILATERAL CONSTRICTED ORBITAL RIMS

Compared to a normal skull, a skull made available for study through the courtesy of Wards Natural Science Establishment Inc. of Rochester, New York, showed smaller orbital rim measurements, with irregularity of the rims, rounded edges, and greater porosity of the bone (Figure 3). Behind the orbital rims, within the orbits, the measurements were normal.

While no known history accompanies this skull, it is my interpretation that these orbital findings are those of a person with bilateral phthisical eyes resulting from diseases which are very common in countries from which such skulls are obtained. Even the presence of phthisical eyes helps to maintain the normal orbital contours but allows the purse-string effect of rim changes. It is thought that this is the skull of a young adult male in his early twenties (Figure 4).

Table 2 compares the orbital measurements of this skull with its bilateral contracted orbital rims with those of a similar normal skull. This comparison reveals the extent of the otherwise subtle changes.

From Table 2 it can be seen that the greatest vertical height measurements inside the orbit remained unchanged. There is an average decrease of 13.3 per cent in the constricted orbital rims and a 16.5 per cent decrease in the orbital volume. Aside from these rim changes, the orbital contour is essentially normal. These changes are compatible with an orbit still housing an eye which is markedly phthisical.

Figure 5 shows the roentgenogram of this skull. There is a greater overhang of the rim due to the purse-string effect, particularly above

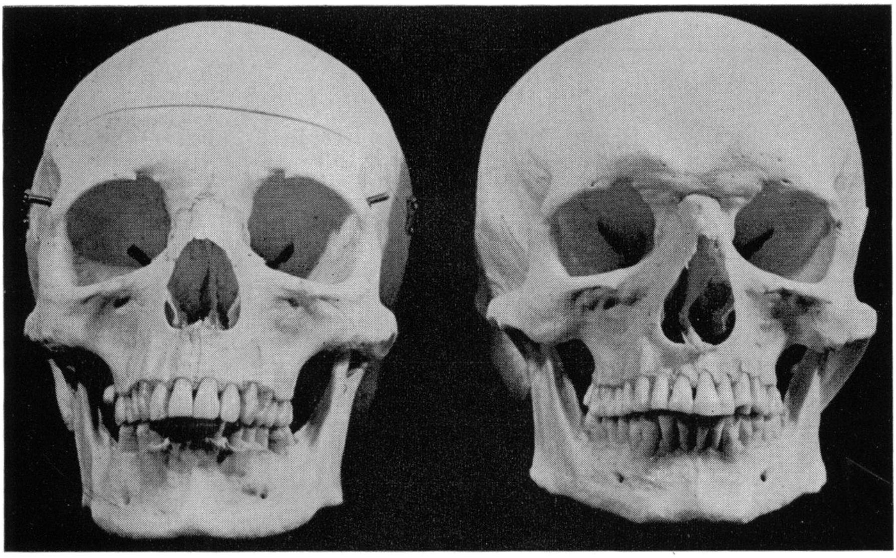

FIGURE 3

Normal skull on the left with regular well outlined orbital rim. Skull on right shows constricted purse-string effect to orbital entrances, which are smaller than in comparable normal skull; rims are irregular, rounded, and bone more porous.

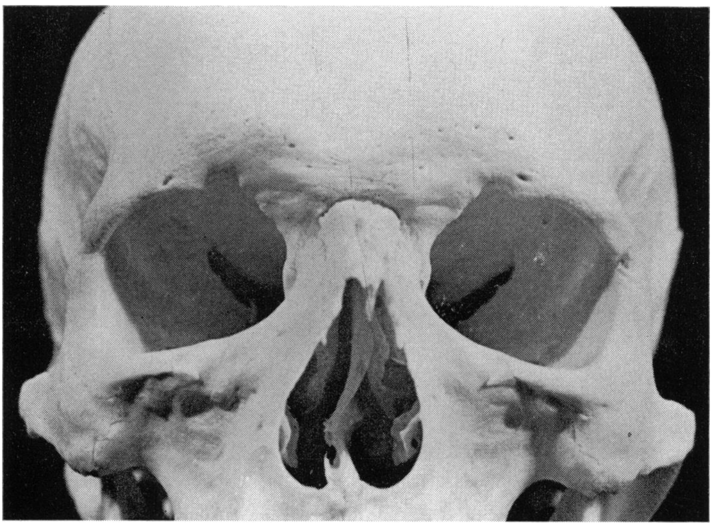

FIGURE 4

Orbits show constricted, purse-string effect; rims are irregular, rounded, and bone more porous.

TABLE 2. ORBITAL MEASUREMENTS

	Height of rim (mm)	Width of rim (mm)	Diagonal UN − LT (mm)	Diagonal LN − UT (mm)	Greatest vertical height inside orbit (mm)	Orbital volume (cc)
Normal skull	33	40	41.2	36	38	30
Constricted rim skull	R 27 L 28	37 36.5	35 35.5	31.5 30.5	38 38	25 25.5
Average percentage difference	16.7	8.1	14.5	13.9	0	16.5
Average percentage difference of orbit entrance measurements	13.3% decrease					

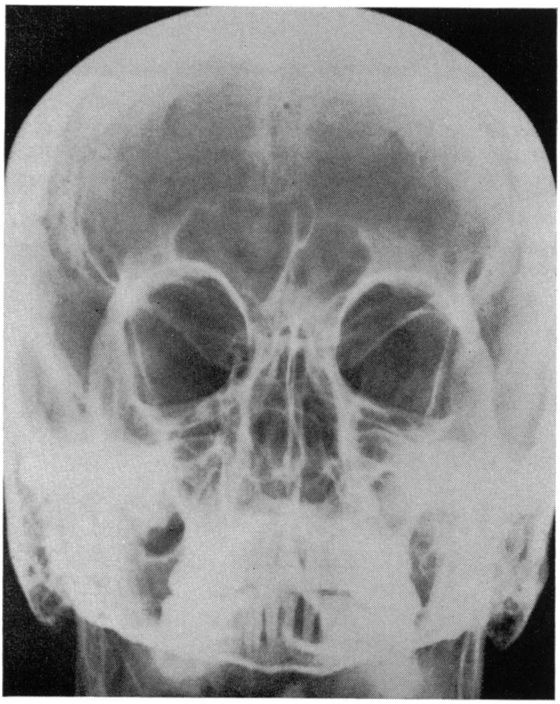

FIGURE 5
Roentgenogram of skull, showing greater overhang of rim due to purse-string effect, particularly above and below.

and below. Figure 6 illustrates the inner outline of the rim of the orbits and the outer outline of the floor, walls, and roof of the orbit traced from the roentgenogram, and points out the greater than normal constriction of the orbital rims.

Of added interest, and probably unrelated, is the incidental finding in this skull of an extensive, old, partially healed temporal parietal right-sided skull fracture (Figure 7).

4. SKULL WITH SMALL CONSTRICTED LEFT ORBIT

A skull of great interest is that of a young person, probably a female in her early twenties, showing a normal orbit on the right side and a small, contracted, abnormal left orbit (Figure 8). No known history accompanies this skull. The left orbit shows marked irregularity and constricted orbital margins which are irregular, rounded, and with increased porosity of the bone (Figure 9). The contour of the walls of the orbit is irregular, with encroachment into the orbit of ethmoid and maxillary air cells.

Figure 10 shows a roentgenogram of this skull with its marked underdevelopment in size of the left orbit and the encroachment of the maxillary and ethmoid air cells and other structures. Figure 11 shows the outline of each orbit traced from the roentgenogram. In this figure the outline of the right orbit is turned like the page of a book to overlay the underdeveloped left orbit, with the shaded area representing the reduction in size.

It is my interpretation that these orbital findings are compatible with those of a person with a normal sized right eye and, quite probably, a congenital anophthalmos on the left, or at least an extremely phthisical left eye from early infancy. The measurements and contour of the orbit would support a congenital anophthalmos despite its rarity.

Table 3 compares the normal right and abnormal left orbital measurements of this skull.

In Table 3 it is noted that the average percentage decrease of orbital entrance measurements is about 25 per cent. Significant changes inside the orbit are present, with a decrease in the vertical height measurement of 16.7 per cent, indicating encroachment by the maxillary and ethmoid air cells. The 20 per cent decrease in the measurement from the midline to the lateral orbital wall, which represents a full centimeter, favors a facial asymmetry which could be of cosmetic concern. The depth of the orbit is decreased on the affected side by almost 12 per cent. The orbital volume is significantly decreased by an astonishing 60 per cent.

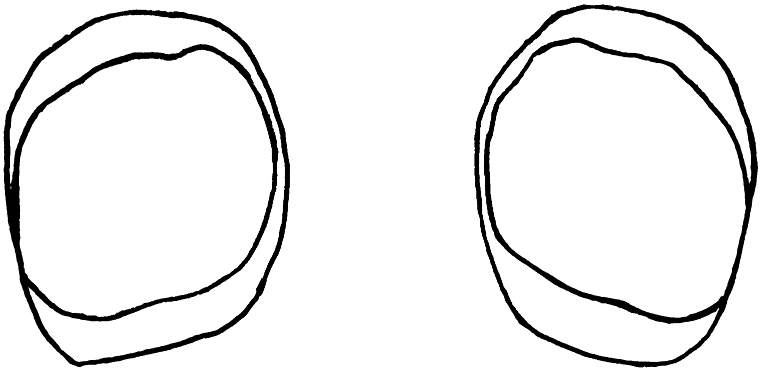

FIGURE 6
Outline of rim of orbit and floor, walls, and roof of orbit traced from roentgenogram, illustrating the greater than normal constriction of the orbital rim.

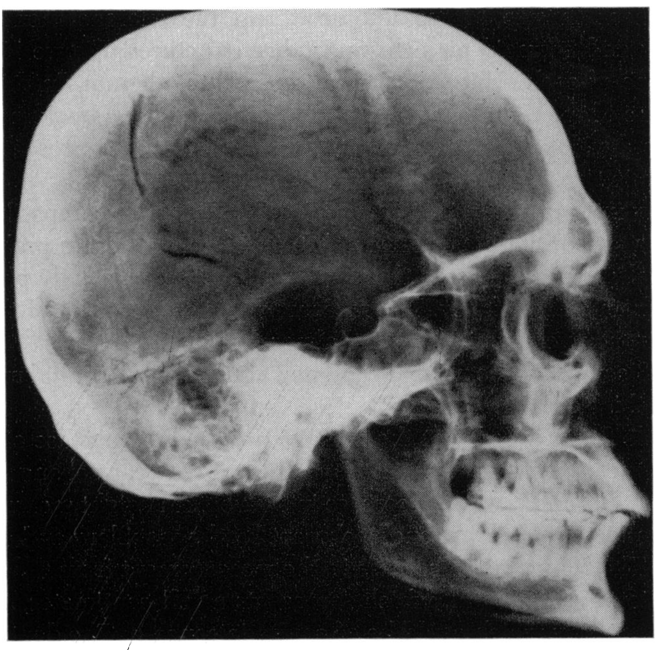

FIGURE 7
Lateral view showing partially healed temporal-parietal right-sided skull fracture, probably unrelated.

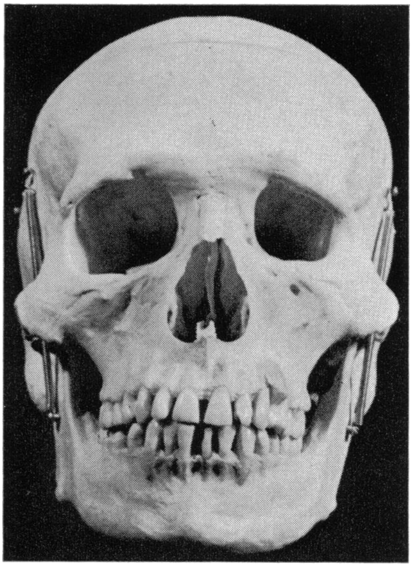

FIGURE 8
Skull showing normal right orbit and markedly underdeveloped abnormal left orbit.

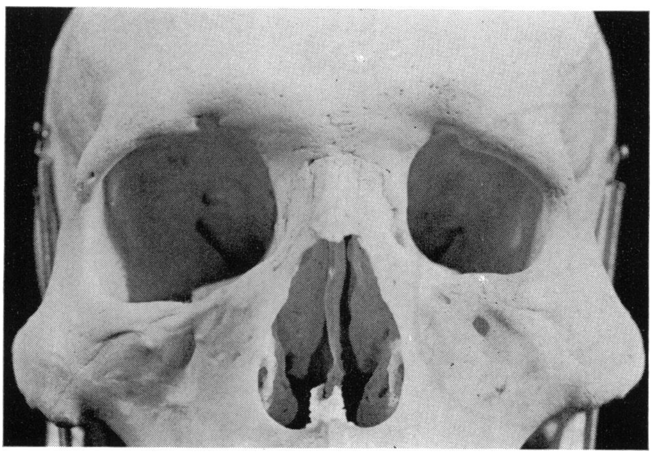

FIGURE 9
Orbital region of same skull, showing underdevelopment of orbit, irregular constricted rim with rounded edges, and increased porosity of bone.

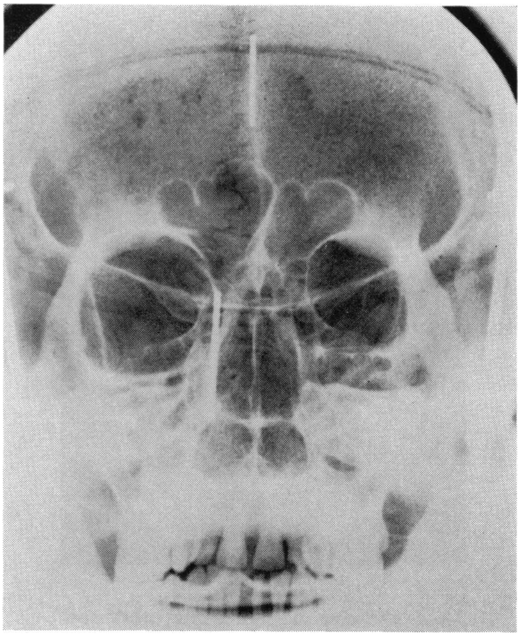

FIGURE 10
Roentgenogram of skull showing underdeveloped left orbit.

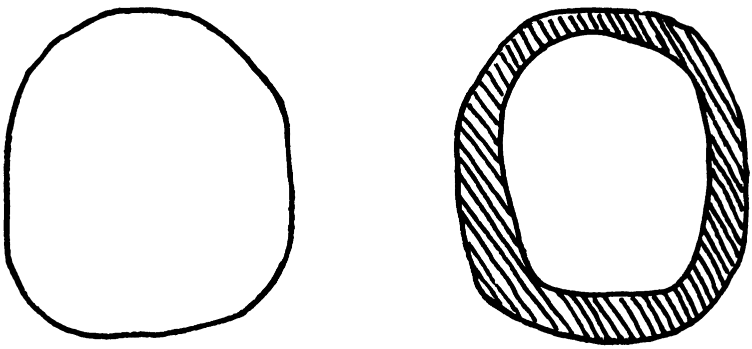

FIGURE 11
Outline of orbit traced from roentgenogram. The outline of the right orbit is turned like the page of a book to overlay the underdeveloped left orbit with the shaded area representing difference in size.

TABLE 3

	Height of rim (mm)	Width of rim (mm)	Diagonal UN – LT (mm)	Diagonal LN – UT (mm)	Greatest vertical height inside orbit (mm)	Midline to lateral orbital wall (mm)	Depth of orbit (mm)	Orbital volume (cc)
Normal right orbit	32	37	39	36.5	36	50	51	30
Constricted left orbit	23	26	30	28	30	40	45	12
Percentage difference	28.1	29.7	25.6	23.3	16.7	20	11.8	60
Average percentage difference of orbit entrance measurements	24.6% decrease							

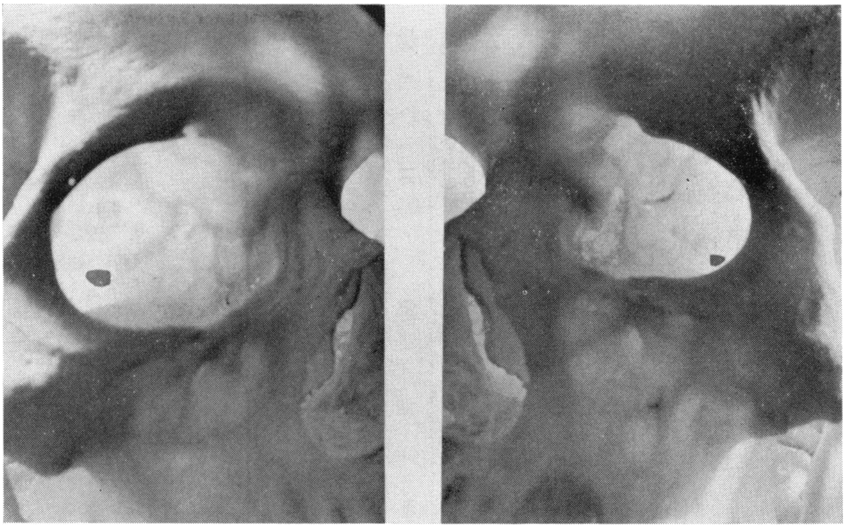

FIGURE 12
Optic canals of dry skull showing marked reduction of foramen size on involved left side when skull is placed in position for roentgenographic examination.

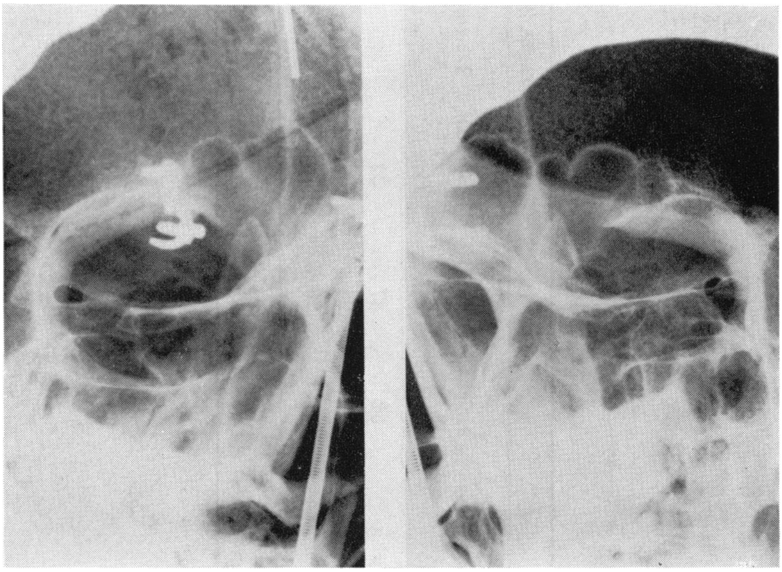

FIGURE 13
Roentgenogram of skull showing reduced optic foramen size on involved left side.

Figure 12 shows the optic canals of the dry skull and Figure 13 the roentgenographic projection of the optic canals to demonstrate the marked reduction in size on the anophthalmic side. These measurements showed a reduction in size of 26.5 per cent on the involved side. It is known that 94 per cent of anophthalmic orbits will demonstrate smaller optic foramina by roentgenographic examination. While this decrease in size may be as much as 50 per cent, it averages 17 per cent.[1] It is noteworthy that the intracranial portion of the optic canal on the affected side of this dry skull revealed a marked reduction in its size.

Other interesting bony changes are seen. With the roofs of the orbits being about the same level, the reduced orbital size is associated with increased measurements of the maxillary bone vertically, expanding into the orbit and raising the floor of the orbit by almost a centimeter. This is accompanied by an elevation of the zygomatic arch on the affected side by a similar amount. The convolutional markings of the brain on the floor of the anterior cranial fossa on the involved side are more diffuse and the bony ridges less pronounced.

DISCUSSION

The two pathologic skulls show interesting findings which confirm roentgenologic knowledge about anophthalmic orbits. The first skull suggests that a retained phthisical eye results in less change in the orbital volume and contour, with the change occurring essentially at the orbital entrance. Roentgen studies of the anophthalmic orbit have proven that there is less orbital development when no buried implant has been used.[1,5] This supports the dictum that elective enucleation should be deferred until most of the growth has occurred. If early enucleation is necessary, an implant is beneficial.

The second pathologic skull with the small underdeveloped orbit demonstrates that without an eye, or with very early simple enucleation, more significant orbital changes occur both at the rim and within the orbit, involving all the dimensions, including height and width of rim, orbital walls, depth, optic canals, and orbital volume.

Koch and Brunetti,[6] in their report of the roentgenologic techniques used to determine the orbital volume and depth of the orbit, concluded that in unilateral anophthalmos the affected side is smaller but retains the same depth as the normal side. The direct anatomical measurements of this pathologic skull with the underdeveloped orbit indicate findings to the contrary, with a 12 per cent decrease in orbital depth on the involved side. The anophthalmic cat orbit has been shown to have a decrease in depth in the magnitude of 11.5 per cent.[1]

Alexander et al.[7] studied the orbital volume of 65 skulls using a sand technique and taking roentgenograms of the skulls. They were unable to make any correlations between the real and roentgen orbital volume. With irregular anophthalmic orbits the determination of volume would be even more difficult.

Therefore this direct anatomic measurement of the anophthalmic orbital volume of 12 cc, when compared to the normal of 30 cc, represents a decrease of 60 per cent, and becomes significant for our realization of the true magnitude of such changes.

The orbital volume has been crudely determined by using the formula of a cone with an elliptical base, with the base measurements being obtained from orbital measurements of the roentgen film. From this the decrease in the orbital volume ranges up to 20 per cent in patients with an orbital implant, up to 30 per cent in patients with no orbital implants, and up to 50 to 60 per cent in congenital anophthalmic patients.[1] The direct skull measurements bear this out.

Clinically the ophthalmologist and ocularist must deal with the patient's concern about his cosmetic appearance. The orbital and cosmetic deformity is greater in the congenitally anophthalmic patient, or when the eye is lost very early in life. In addition to making it possible to realize the difficulties with the conjunctival socket, our roentgenologic studies and direct anatomic measurements should emphasize the fact that the bony orbital changes are also of significance.

One might wonder about the frequency of this type of problem. In a recent report from one office over a ten-year period the ocularists were confronted with the treatment of 36 congenital monocular anophthalmic patients and seven bilateral patients.[8] This was in addition to those cases of surgical anophthalmos. This incidence suggests that congenital anophthalmos occurs much more frequently than is reported in the literature.

In the treatment of congenital anophthalmos, or extreme microphthalmos, the problem is to transform a small inadequate socket into one that will retain a satisfactory prosthesis with a reasonable cosmetic result. If untreated in childhood, the problem may be more difficult to handle with increased growth and greater disparity. The usual approach for socket enlargement has been various surgical dissections of the lids and socket with the addition of lining with skin or mucous membrane. While these methods can produce larger sockets, the result may be unsatisfactory. Scar tissue can limit all motility of the prosthesis. Skin grafts may have offensive discharge, and it may be difficult to obtain enough mucous membrane. Lid margin surgery may leave an unnatural appearance and a disturbance in the eyelash line.

Spaeth[10] has recommended the early insertion of an orbital implant for congenital anophthalmos and feels that all such patients will need socket grafts. The insertion of an implant, however, if performed trans-conjunctivally, will only add more scar tissue to an already small socket. If the volume of the anophthalmic orbit, however, has been reduced 60 per cent, to about 12 cc, it is a question of whether the gain from a small orbital implant would be offset by the added scar tissue produced by the surgery.

For the small bony anophthalmic orbit Cole has suggested cutting through the periosteum at the orbital margin, with removal of bone to enlarge the bony socket, followed by mucous membrane grafts.[11]

Mustarde[12] feels that such cases will not benefit from dilatation and that they are best left alone until the patient is about 12 years of age, following sinus development, when they should be treated surgically. An adequate socket must be produced and room for it obtained. This surgery consists of a lateral canthotomy, excision of the rudimentary socket, removal of bone from the lateral and inferior orbital margins, and insertion of a skin graft for total socket reconstruction.

Small repeated surgical procedures performed in an attempt to improve a small contracted socket are to be condemned. These can only add more scar tissue and contracture, which is continual and relentless, and can transfer a moderate socket problem into a severe or insurmountable one.

The ideal treatment is a conservative approach consisting of progressive dilatation[8,11,13] of the socket through mechanical means. This can be done either by taking an impression of the socket and, as the socket will accept the changes, using progressive additives to the impression expander, or by using conventional stock conformers of increasing size.

This method can be very satisfactory, but the essential requirement for success is the opportunity to begin treatment early in infancy. Treatment should be started by the age of one month. Such early treatment may well give a satisfactory cosmetic appearance and avoid the extensive surgical procedures which often give a less satisfactory cosmetic result. Dilatation can be accomplished readily if it is begun in infancy, during the period of rapid growth when the bone and soft tissue are more mobile and acceptable.[13] The procedure of waiting until the patient is old enough to cooperate does not serve his best interest. Anesthesia may be necessary if the patient is too young for satisfactory cooperation.

While a large number of patients may require minor surgical procedures at some time, this technique should reduce to about 30 per cent the number of refractory patients who may need radical or multiple surgical procedures.[14]

The reduction of the linear orbital measurements by approximately 25 per cent, and of the volumetric measurements by 60 per cent of normal, has been proven. This reduction necessitates the acceptance of a smaller prosthesis. This fact must be realized and, if a satisfactory cosmetic result can be obtained, it must be accepted even if it falls short of perfection.

If the measurement from the midline to the lateral orbital margin is reduced by as much as one centimeter, there seems to be little or no added cosmetic defect.

When enucleation is performed there is also deformity of the orbit. As previously mentioned, however, the deformity is significantly less than in the congenital anophthalmic patient, and with a prosthesis a satisfactory to excellent cosmetic result is possible.[15,16,17]

If indicated in the anophthalmic orbital patient the orbital volume can be increased by glass bead insertion into the orbit without extensive surgery or interference with the conjunctiva.[18]

From roentgenographic study and bone measurements of skulls with abnormal orbits we cannot yet correlate measurements to determine the volume of the orbits. However the opportunity to study such abnormal skulls sheds light upon the actual extent of the change which we are confronted with from a practical clinical standpoint. On the basis of the actual linear and volumetric measurements of these two abnormal skulls, it seems that changes of the orbital volume calculated from linear measurements from the roentgenogram probably still provide adequate approximate guidelines for clinical application.

If surgery is contemplated for an anophthalmic orbit which has abnormalities, it should be emphasized that careful preoperative roentgenographic studies should be made. Such an evaluation should include stereoscopic projections, or tomography, so that the changes in the walls of the orbit, in addition to the orbital rim changes, can be appreciated, and the orbit studied as a cavity.

SUMMARY

Two skulls with orbital abnormalities, in which linear measurements and volumetric measurements have been determined, are described. The findings give better insight into the clinical problems associated with management of the anophthalmic orbit.

Patients with congenital anophthalmos may show a decrease in orbital entrance measurements in the magnitude of 25 per cent. The orbital walls may show a different contour and encroachment into the orbit. The orbital depth, previously thought to be unchanged in the anophthalmic orbit, may show a decrease in the magnitude of 12 per cent. The orbital volume is significantly decreased, in the magnitude of 60 per cent. The reduced size of the optic foramen of the anophthalmic orbit, as noted roentgenographically, is confirmed by direct measurement.

Clinically a conservative management for the congenital anophthalmic patient, consisting of progressive dilatation of the socket by mechanical means, is advisable. Molds made from socket impressions, or conventional stock conformers, can give excellent results if treatment is begun in the early weeks of life. Extensive surgical procedures can frequently be avoided if conservative treatment is started early enough, but may be needed in the infrequent refractory patient.

In patients with orbital abnormalities complete roentgenographic evaluation should be made and the orbit studied as a cavity before surgery or treatment is undertaken.

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DISCUSSION

Dr Crowell Beard. When I read the abstract of Dr Kennedy's paper in the program and agreed to discuss this excellent presentation, I hoped that I, too, might be able to obtain a skull with an anophthalmic orbit. Our anatomy laboratory contained no such skull, and my anophthalmic patients seemed uninterested in cooperation. They were even unwilling to submit to exenteration to permit volume measurements to be taken.

[Slide] I present photographs and a roentgenogram of one patient who has a decrease in measurement from midline to lateral orbital margin of 6 mm on the anophthalmic side as compared to the normal side. These confirm Dr Kennedy's statement that this difference adds little or no cosmetic defect.

[Slide] Another photograph and roentgenogram show a small orbit which resulted from enucleation for retinoblastoma followed by extensive radiation. A contracted socket was treated by repeated surgical insults, and an unsatisfactory result was obtained. Surgical correction of contracted or undeveloped sockets has invariably been disappointing in my hands.

An infant eye has a volume of about 2.1 cc. An adult eye has a volume of about 6.4 cc. A 14-mm sphere has a volume of about 1.4 cc, while a 20-mm sphere has a volume of about 4.2 cc. The average prosthesis has a volume of close to 1 cc. To traumatize repeatedly an orbit by increasing the size of implants from 14 to 20 might furnish a volume equivalent (when added to the prosthesis volume) to that of the growing eye; but the cosmetic effect would be on the negative side.

I agree with Dr Kennedy that conservative treatment consisting of the early use of conformers to help the socket to form is far more valuable than are repeated operations. A skillful ocularist, a patient parent, and an interested ophthalmologist are prerequisites for the limited success obtainable. Late implantation of glass beads or other material may improve motility slightly and may fill out a supratarsal sulcus, but surgery should be kept at a minimum. The size of the socket is more important than is the size of the orbit.

I wish to thank Dr Kennedy for his valuable presentation, and also for sending me an advance copy of his paper.

Dr Kennedy. I want to thank Dr Beard for his very gracious comments. I am glad to see he has conservative thoughts on the management of this problem. Like Dr Beard, I too have had poor patient participation in this project, with no one giving up his skull. My barber has a saying on the awning of his shop, "We Need Your Head in Our Business." I can't tell you how many times I have thought of this saying when I have seen the ideal patient in the office whom I would like to have cooperate a little bit and lend us his skull.

It would be nice to have a series of skulls, obviously, with such abnormalities. However, as Dr Beard pointed out, he found none in his institution. In preparing my AOS thesis I canvassed eighteen institutions, including medical and dental schools and the Armed Forces Institute of Pathology, and only after a 12-year hunt have these two skulls become available. Dr Beard mentioned that the reduction in the midline to the lateral wall measurement has little influence cosmetically, and I agree with this. In females, with their various hairdos, this cosmetic defect might be even less noticeable.

[Slide] This is a female who, even if she did have trouble with her left eye, combs her hair in such a way that if you were to meet her casually on the street you would not even notice the left eye difficulty.

Seriously, as Dr Coleman mentioned just before he ran out the door of the meeting yesterday, with his ultrasonic measurements the potential of measuring these deformed orbits clinically might well be much better than our study of them roentgenographically.

Radiation effects were mentioned by Dr Beard, and this problem should certainly be given consideration because of the involvement of the soft tissue and the bone by the radiation, which compounds the problem of the anatomical maldevelopment anyway.

[Slide] This is a slide of a 14-year-old with a rhabdomyosarcoma that was heavily irradiated and enucleated when he was 9. At age 22 he is still alive. This is the film taken of him at age 14. You can see the very marked destruction on this side, and the much smaller orbit. In addition to the smaller orbit there is tremendous bone destruction. If you are thinking surgically you will have to operate on both abnormal tissues and deal with this bone deficit.

[Slide] Another example is a patient who had bilateral retinoblastomas. This film was taken at age 13. The left eye had an enucleation when the patient was 7 months old, and a spherical implant. The right eye contained a retinoblastoma and was very heavily irradiated. The tumor progressed, and at age 3 this eye was removed and an implant placed. This orbit would be expected to be larger, because it had housed the eye for a longer period of time; but actually it is 12 per cent smaller than the orbit in which the eye had been removed at an earlier age. This shows the very significant growth retardation effect of irradiation.