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Morphological changes in the zygomatic arch during growth

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Abstract Morphometry of the zygomatic arch was obtained using 30 Indian dried skulls at each of Hellman's dental stages: IIA, IIIA, IIIB, IVA, and VA, for a total of 150 skulls 300 sides. The following conclusions were obtained.

1. Though both the height and length of the zygomatic arch increased at all stages from IIA to VA, the rate of increase of the height indicated a value larger than the length.
2. The zygomaticotemporal suture consisted of the vertical element from the upper margin to the center and the horizontal element from the lower side to the margo inferior during the IIA period. This suture changed to a gradual curve from the upper margin to the margo inferior with the movement of the center and the lower side to the rear during the VA period.
3. The degree of interdigitation of the zygomaticotemporal suture increased from the IIA period to the IIIA and IIIB to IVA.

These findings suggest that the form of the zygomatic arch and the zygomaticotemporal suture showed growth change adjusting to the functional change in mastication with growth.

Key words
Morphometry,
Growth and development,
Zygomatic arch,
Zygomaticotemporal suture

Introduction

The zygomatic process of temporal bone projects to the exterior, then bends forward, connecting with the temporal process of the zygomatic bone forming a suture (zygomaticotemporal suture) that runs downward. The zygomatic bone forms the frontozygomatic suture at its border with the frontal bone and the zygomaticomaxillary suture at its respective borders with the maxillas and it is thought that the zygomatic bone receives and distributes stress from biting force to the surrounding bone[1–3]. In addition, stress is received through the mandibular fossa when chewing. Many reports have described the routes of stress distribution to the cranial bones[4–7]. The masseter muscle adheres to the zygomatic arch, and various mechanical traction forces are applied from the muscle when biting. It is thought that the form of the zygomatic arch is influenced by numerous environmental factors like changes in the dentition and development of the masticatory apparatus. However, there are few reports describing morphological changes in the zygomatic arch in relation to growth[8]. In this study, the zygomatic arch during the growth stage was examined by morphometry.

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Materials and Methods

The materials in this study consisted of 150 Indian skulls in the possession of Division of Oral Anatomy, Department of Morphological Biology, Ohu University School of Dentistry. These skulls demonstrate normal occlusion, no defects in dentition and no dental caries.

These materials consist of five groups of 30 skulls each in Hellman's dental stages IIA, IIIA, IIIB, IVA, and VA, respectively in a total of 150 Indian skulls, 300 sides. The teeth that reached the line of occlusion was assumed to have completed the eruption.

The plane including three points: the each side external auditory meatus upper margin (po) and left

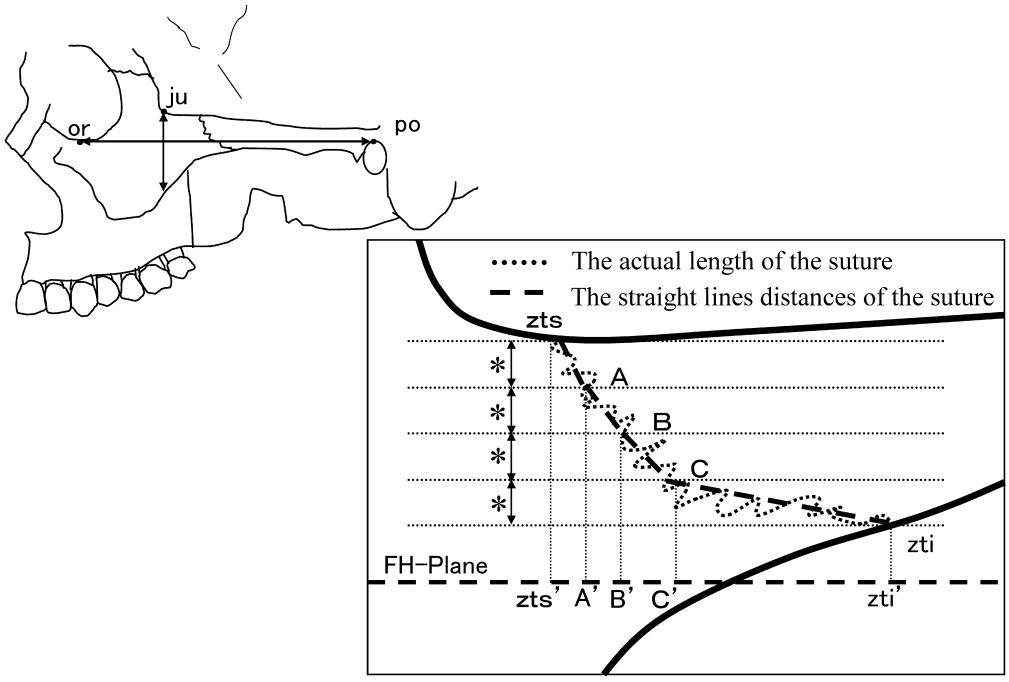

Fig. 1 Setting of reference points for measurement of the position of the zygomaticotemporal suture

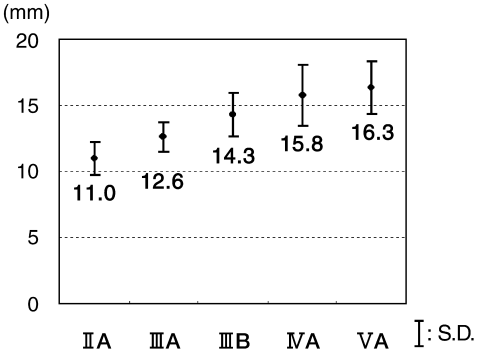

Fig. 2 The height of the zygomatic arch

Table 1 The height of the zygomatic arch

	ⅡA	ⅢA	ⅢB	ⅣA	VA
ⅡA					
ⅢA	**				
ⅢB	**	**			
ⅣA	**	**	**		
VA	**	**	**	N.S.	

N.S.: not significant; **: $P<0.01$

orbitale (or) was defined as the Frankfort horizontal plane (FH plane), and the plane including nasion (n), inion (i), and basion (ba) was defined as the median plane. Photographs of the right and left side from direction orthogonal to the median plane of the skull with the FH plane fixed parallel to the floor were obtained using a digital camera after the craniometric points had been marked. Analysis of these measurement items were performed using the public domain NIH image program (developed at the U.S. National Institutes of Health and available from the Internet by anonymous FTP from zippy.nimh.gov or floppy disk from the National Technical Information Service, Springfield, Virginia, part number PB95-500195GEI).

The definition of the measured items are as follows.

The distance vertical to the FH plane between the upper margin and the margo inferior of the zygomatic arch in the jugale (ju) was measured as the height of the zygomatic arch. As the zygomatic arch length, a straight line from the orbitale (or) to the porion (po) was measured. After dividing the distance between two straight lines parallel to the FH plane passing through the upper margin (zts) and margo inferior (zti) of the zygomaticotemporal suture into four and three straight lines parallel to the FH plane passing through these point, the point

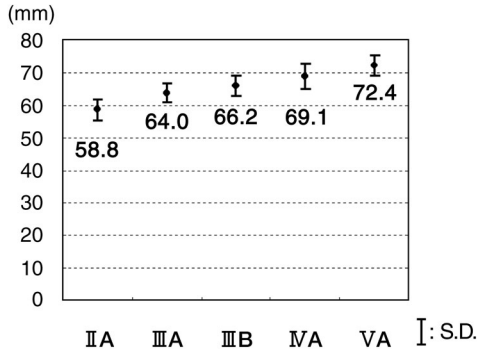

Fig. 3 The length of the zygomatic arch

Table 2 The length of the zygomatic arch

	IIA	IIIA	IIIB	IVA	VA
IIA					
IIIA	**				
IIIB	**	**			
IVA	**	**	**		
VA	**	**	**	**	

**: $P<0.01$

Table 3 The position of the zygomaticotemporal suture (%)

	IIA	IIIA	IIIB	IVA	VA
zts'	36.2±4.6	35.7±4.2	35.7±3.9	35.6±3.9	36.4±4.1
Point A'	36.5±4.2	36.2±2.9	36.0±3.7	36.3±3.6	37.4±4.0
Point B'	36.7±3.5	36.6±3.0	36.4±3.3	37.7±3.1	38.7±4.4
Point C'	42.8±6.2	43.1±5.8	42.1±4.6	42.7±4.8	44.9±6.1
zti'	49.8±4.2	49.1±4.8	48.4±4.0	48.5±4.2	48.7±4.8

(mean±S.D.)

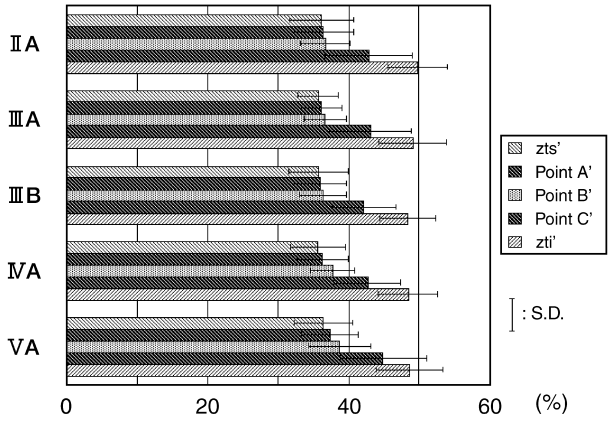

Fig. 4 The position of the zygomaticotemporal suture

of intersection of these lines with the border of the zygomatic process of the zygomaticotemporal suture were defined as points A, B, and C in sequence from superior to inferior. Perpendicular lines were drawn from zts, zti, point A, B, and C to the FH plane, and the points of intersection with the FH plane were defined as zts', zti', point A', B' and C'. The distance from each point to the orbitale (or) was divided by the zygomatic length and the value was expressed as a percentage, and was assumed to be the position of the suture. The degree of interdigitation of each suture was estimated by tracing the path of the border of the zygomatic process at the zygomaticotemporal suture, then dividing by the distances of straight lines that connect zts with points A, B, C, and zti respectively (Fig. 1).

Unitary arrangement decentralization analysis was performed, then multiple comparison verification was performed when a significance difference was detected.

Results

The height of the zygomatic arch at the jugale (ju) significantly increased with progression from stage IIA to stage IVA (Fig. 2, Table 1). The zygomatic arch length significantly increased with progression from stage IIA to stage VA (Fig. 3, Table 2). On comparison between each stage, the position of the suture in the zygomatic arch remained almost constant at zts', point A', and zti'. However, the position of point B' significantly increased from stage IIIB to stage IVA and the position of point C' significantly increased from stage IVA. On comparison between each points, there was no significant difference in

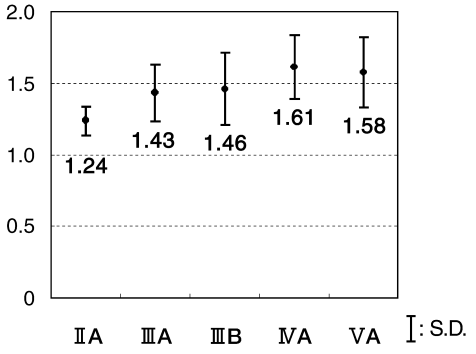

Fig. 5 The degree of interdigitation of the zygomaticotemporal suture

Table 4 The degree of interdigitation of the zygomaticotemporal suture

	IIA	IIIA	IIIB	IVA	VA
IIA					
IIIA	**				
IIIB	**	N.S.			
IVA	**	**	**		
VA	**	**	**	N.S.	

N.S.: not significant; **: $P<0.01$

the three positions of zts', points A', and B' during progression from stage IIA to stage IIIB, but there was a significant difference in the positions of points A' and B' at stage IVA, and the positions of zts' and points B' at stage VA (Fig. 4, Table 3). The degree of interdigitation of the suture significantly increased from stage IIA to stage IIIA, and from stage IIIB to stage IVA (Fig. 5, Table 4).

Discussion

It is said that the zygomatic arch transmits functional pressure to a surrounding bone during mastication[1–7]. Moreover, various mechanical influences have been received as an adherent part of the masseter muscle. In the present study, to measure the form of the zygomatic arch during growth as well as to evaluate the development of the zygomaticotemporal suture, the degree of interdigitation of the suture was measured.

Regarding the size of the zygomatic arch, there was a tendency for both height at the jugale (ju) and length from the orbitale (or) to porion (po) to increase from stage IIA to stage VA. The zygomatic arch length increased 1.28 times from stage IIA to stage VA, while the height of the zygomatic arch increases 1.48 times. The rate of increase in the height of the zygomatic arch was larger than that of the length of the zygomatic arch. It is thought that this difference occurs because the length of the zygomatic arch is influenced by the growth of the cerebral cranium, which increases remarkably until the deciduous dental arch period[8].

Measurement of the position of the suture showed that there were no changes at the upper margin (zts), margo inferior (zti) and upper region (point A) of the suture from stage IIA to stage VA. The movement of the suture in the posterior direction was observed at the central region (point B) starting at stage IIIB and at the lower side region (point C) starting at stage IVA. That is, there was a gradual change to a slight curve from the upper margin to the margo inferior by stage VA, even though the suture remained an essentially vertical element from the upper margin to the central region with a horizontal element from the lower side region to the margo inferior at stage IIA. On electromyographic measurement, it is thought that the amounts of muscle activity of the masseter muscle and the temporalis muscle remain almost the same during the deciduous dental arch period, but the masseter muscle becomes more predominant from stage IIIB and the difference increases during the permanent dentition stage[9]. It was thought that functional changes due to such mastication muscles also influenced changes in the position of the suture. It is assumed that a large force is distributed to anterior zygomatic arch compared with that the posterolateral region in *macaca fascicularis*, and is suggested to be due to the influence of the masseter muscle[10]. Moreover, it is assumed that according to the concentration of stress by adhesion of the masseter muscle and the temporalis muscle fascia, the trabecular structure at the jugale (ju) area of the zygomatic bone becomes thicker than that in other regions[11]. However, based on measurements of masticatory strain and the double labelling method in a miniature pig, functional tension at the suture was not correlated with the sutural growth rate[12].

Sicher[13] assumed that the zygomaticotemporal suture participated in the forward growth of the maxilla complex. In this study, change was observed

in the position from the lower region to the margo inferior of the suture after stage IIIB, and it was thought that the suture also received an effect from growth changes in the masticatory apparatus.

Sutures other than zygomaticotemporal suture contribute to lateral displacement of the zygomatic bone, but the temporal bone receives about threefold larger rate of deposition on the lateral surface than the zygomatic bone and thus shows less effect[14]. It was thought that the difference in growth pattern between the zygomatic bone and the temporal bone also influences the morphological change at the zygomaticotemporal suture.

As a result of three point bending test, it is assumed the suture with a larger degree of interdigitation of the suture (actual length/straight line distance of the suture) is more resistant to bending[15]. The degree of interdigitation of the suture was measured to evaluate the development of the zygomaticotemporal suture. As a result, interdigitation increased from stage IIA to stage IIIA and from stage IIIB to stage IVA. Before the period of deciduous dentition, the suture was rectilinear due to the influence of the remarkable cranium growth[8]. During deciduous dentition, many bone extensions are formed and the degree of interdigitation of the suture increases. Results of transplantation experiments suggest the sutural structures was determined not only by inheritance but also by mechanical factors and marked amounts of osteoid were found in the tips of the lingulae showing a direction corresponding to growth[16]. It was thought that an increase in the degree of interdigitation of the zygomaticotemporal suture was influenced by not only change in the dental arch form but also changes in functional factors such as increases in the activity of the masseter muscle attached at the suture. In the tensed suture, collagen fibers run straight, whereas in the compressed suture, the fibers are arranged obliquely, therefore, load to the sutural margins is transmitted in a tensile manner[12,14,16,17]. It has been reported that the application of tension in the periosteum leads to the addition of bone[18].

It was thought that the forms of the zygomatic arch and the zygomaticotemporal suture were affected by growth change, adjusting to the growth of the masticatory apparatus.

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