Remodeling Reversals in Anterior Parts Of the Human Mandible and Maxilla

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The objectives of this study are (1) to determine the *timing* for the onset of the characteristic fields of external surface *resorption* in the anterior regions of the maxilla and mandible and (2) to describe *variations* in the development and pattern of these resorptive fields.

In previous studies utilizing a series of human skulls from about six years of age through the mixed dentition period, the existence of outer surface *resorptive* fields was demonstrated histologically.[4,5] In a study of human prenatal specimens[10] it was shown that periosteal surfaces corresponding to these same locations are *depository*. At 26 weeks of prenatal development most of the maxillary and mandibular resorptive and depository remodeling fields that characterize the postnatal period have already been established. One principal exception is the anterior part of the maxilla and mandible. Thus, at some period between birth and about six years, reversals are known to occur from depository to resorptive in these locations. The present study was undertaken to more precisely pinpoint the timing involved. Developmental and functional factors that might relate to the timing of these reversals, also, have to date not been explained and this is another purpose of the present study.

The existence of resorptive outer surfaces in the forward part of human upper and lower jaws is apparently a unique feature of *Homo sapiens* since this feature does not occur in any other species studied to date including primates.[6] In the face of mammals having a protruding muzzle the nasomaxillary complex and mandible grow by progressive new bone deposition in forward as well as backward and downward directions. Conversely, in the essentially muzzleless human face subsequent to the characteristic reversals mentioned above, the alveolar bone of the upper and lower jaws grows vertically but does not provide horizontal arch elongation by direct bone growth on *anterior-facing* surfaces. Rather, horizontal lengthening of the bony arches is produced almost entirely by a posterior mode of bone formation at their posterior ends (in conjunction with a process of anterior displacement of the whole mandible and maxilla). Vertical growth at the alveolar crest produces a relatively small extent of maxillary arch lengthening associated with deciduous and permanent incisor eruption. While the outer (periosteal) surface of the cortical bone of the anterior part of both arches is resorptive, the contralateral endosteal surface is depository. The bone in this region grows in an endosteal rather than a periosteal direction. For the maxilla this provides a *downward* but not forward direction of progressive growth of the arch. For the mandible it produces an upward and lingually-inclined direction of incisor alveolar growth movement.[6]

From Case Western Reserve University, Cleveland, Ohio and supported in part by USPHS Grant DE05078.

These histologic observations substantiated earlier cephalometric conclusions by Brodie,[3] who noted a "relative dropping back" of the incisor region during growth, and the implant studies of Björk showing similar findings.[1,2]

Materials and Methods

A group of 36 human dry skulls from around birth to fourteen years of age was utilized. The specimens were purchased from commercial anatomical supply houses and documentation as to sex and ethnic history was not available. To provide reliable dental age determinations, bite-wing X-ray pictures of the upper and lower arches were taken for all specimens to assess stages of dental development.[9,13] The series of skulls was then classified into four groups according to these stages: Stage I, perinatal; Stage II, before eruption of any primary teeth, or during early primary dentition period after appearance of the mesiobuccal cusp of the unerupted lower permanent first molar on X-ray films; Stage III, primary dentition after eruption of the lower primary second molar; and Stage IV, mixed dentition. The criterion used to distinguish Stage IV from Stage III was the eruption of the lower permanent first molar.

From the right side of each skull the entire maxillary region from just posterior to the key ridge to the anterior tip of the bony arch was removed for sectioning. For the mandible the entire region mesial to the deciduous second molar or permanent first molar was removed from each mandible's right side. The left sides of both the maxilla and mandible were retained so that gross anatomical and topographical features could be related to histological findings. Specimens were cut into blocks approximately 1.5 to 2.0 cm square, decalcified, completely serially sectioned at 10 microns, and stained with hematoxylin and eosin. Each and every section was analyzed for the distribution of surface fields of deposition and resorption. A montage representing each entire specimen was then prepared showing the precise, over-all pattern of maxillary and mandibular remodeling for that individual skull (Figs. 1 and 2).

Observations

Stage I. A typical type of nonlamellar bone tissue termed "fine cancellous"[6] comprised virtually the entire extent of each specimen at this age level, as it does throughout the fetal period of development.[10] A distinct cortex, as such, is lacking.

The outer (labial and buccal) sides of the forward part of both the maxillary and mandibular arches are entirely depository in nature. No evidence of any surface resorptive activity is seen. The lining surfaces of each alveolar crypt housing the unerupted tooth buds, however, are uniformly resorptive in conjunction with progressive tooth enlargement. The maxillary and mandibular bony arches are growing and elongating in an anterior direction during this age period as they also simultaneously lengthen posteriorly at the maxillary and lingual tuberosities. This accommodates the mesial as well as distal expansion of the dental arches and the fine-cancellous nature of the bone tissue involved indicates a rapid pace of growth.[6]

Stage II. Surface resorption is still absent (except for the alveolar crypts) in all of the mandibular specimens. In the maxilla, however, surface resorption has now begun in limited distribution for four of the five specimens studied at this age level. This initial

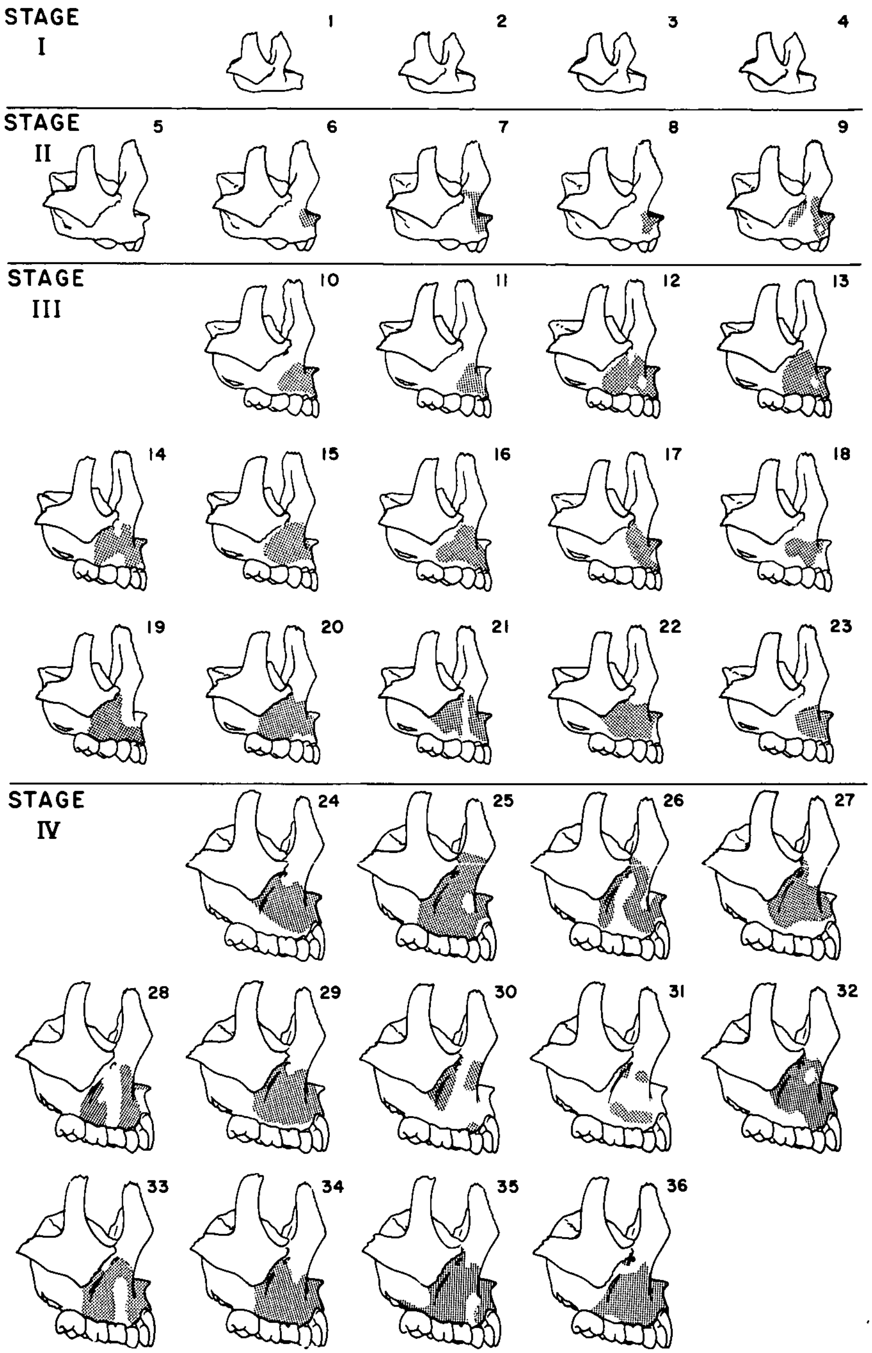

Fig. 1 Arranged in chronologic sequence from the perinatal period to 14 years, the pattern of surface resorption on the maxilla in 36 different individuals is indicated by the shaded areas. Key to ages: Numbers 1-4, perinatal; No. 5, 2 months postnatal; No. 6, 3 months; No. 7, 4 months; No. 8, 5 months; No. 9, 10 months; Nos. 10-11, 2 years; Nos. 12-15, 3 years; Nos. 16-18, 4 years; Nos. 19-23, 5 years; Nos. 24-28, 6 years; Nos. 29-30, 7 years; No. 31, 8 years; Nos. 32-33, 9 years; No. 34, 10 years; No. 35, 11 years; No. 36, 14 years.

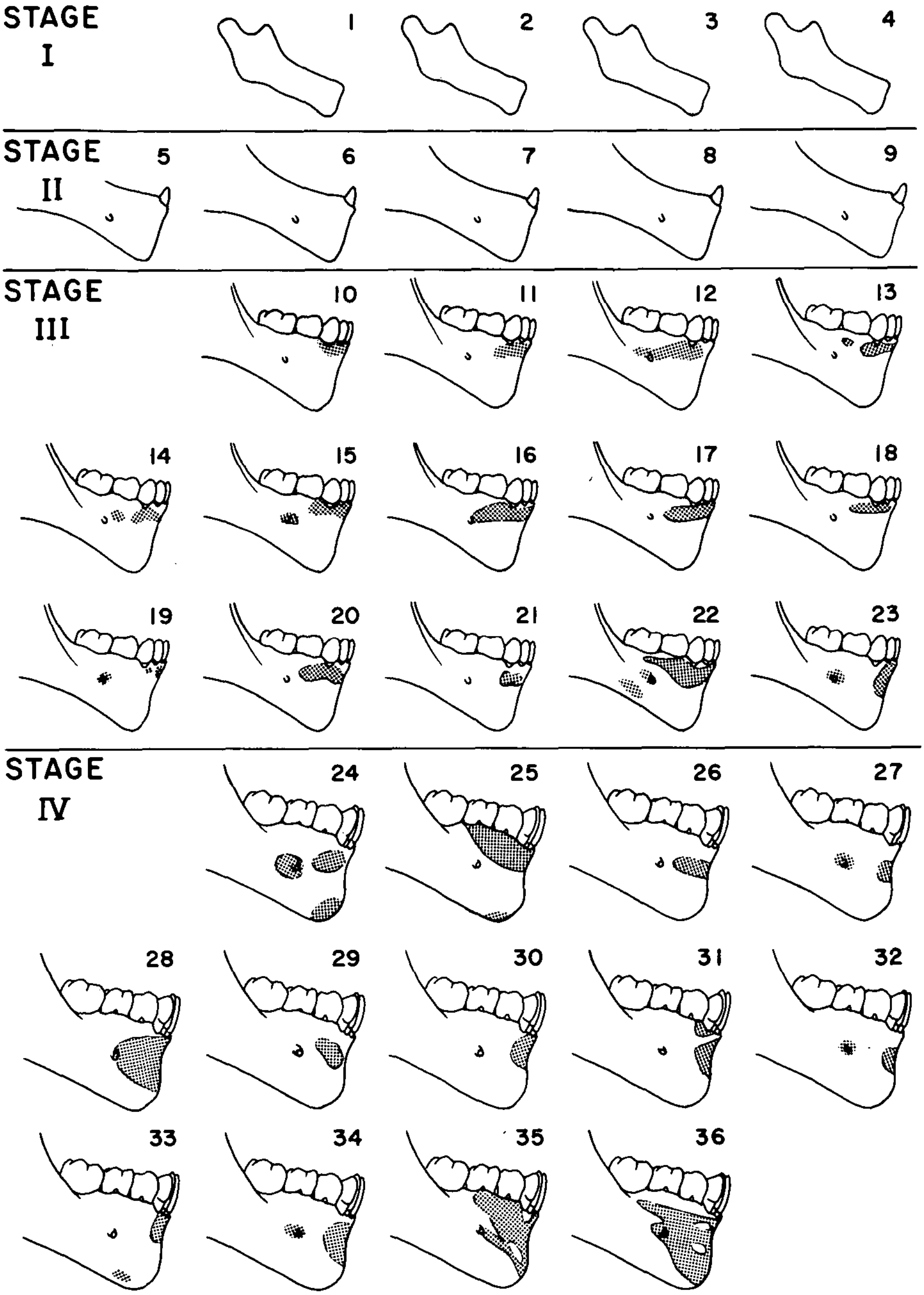

Fig. 2 The surface pattern of resorption in the anterior part of the mandible is shown in the same 36 individuals represented in Figure 1.

appearance is in the premaxillary and contiguous nasal regions just inferior and lateral to the bony nasal orifice. The one specimen in which no resorption at all was observed was the youngest of the five specimens (estimated to be 2 months of age postnatal). The second youngest specimen (3 months) showed only a small resorptive area. The bony linings of the alveolar crypts are all resorptive, as they were in Stage I. The rest of the external surface of the maxillary arch remains depository.

The cortex-lacking, fine-cancellous nature of the bone seen in Stage I is now becoming superseded by more compact bone tissue having a more distinct cortex. Coarse-cancellous trabeculae are beginning to replace the original fine-cancellous bone in medullary regions.

Stage III. On the maxilla the surface resorptive field has now spread laterally, posteriorly and inferiorly. It has reached the infraorbital foramen and extends back to the level of the key ridge (or nearly so) in most of the specimens. This enlarging resorptive field has also reached an inferior level near, but not quite at, the alveolar crest. This is its definitive inferior-most boundary in most specimens through the remainder of facial growth.

For the mandible in Stage III a surface resorptive field has now appeared for the first time, thus lagging considerably behind the timing observed for the maxilla. It occurs as a narrow zone high in the alveolar region and extends from the symphysis posteriorly to the level of the first or second deciduous molar.

The bone tissues of the mandible and maxilla show a continuing decrease in the extent of fine-cancellous bone and a progressive increase in compact cortical bone and medullary, coarse-cancellous trabeculae.

Scattered irregularly over the resorptive surfaces, a few very small, thin "spot" deposits of periosteal bone have been laid down. These are believed to represent transient, localized cortical adjustments to tooth movements occurring during eruption and drift.[5] They provide cortical cover for small bulges or convexities over tooth roots and erupting crowns that otherwise would appear as "fenestra" in the resorptive cortical surface as the arch grows downward while the teeth simultaneously undergo varieties of movements.

Stage IV. The maxillary resorptive pattern established in Stage III continues into Stage IV and in most specimens covers most of the surface anterior to the key ridge. The perimeter of this sizable maxillary resorptive field is quite irregular and highly variable among all of the different individual specimens. No two are quite alike, although the general configuration is similar among most specimens.

In the mandible the resorptive field has spread in most specimens and now covers a larger, irregular area extending distally to the level of the canine or premolar region and, in some of the older specimens, back to the area of the mental foramen. As in the maxilla, the exact circumferential configuration of this resorptive area is quite variable among the different individual mandibles. Covering the mental protuberance in most specimens is a relatively sparsely-vascularized, lamellar type of bone tissue indicating a slow pace of depository growth. As the alveolar region superior to the chin undergoes a regression, the chin itself gradually grows farther anteriorly. This two-way growth pattern thus gives rise to the slowly enlarging mental protuberance and relates to the overbite and overjet incisor relationship of the human teeth.

TABLE I

Stage	Period	*Anterior surface resorption of maxilla*	*Anterior surface resorption of mandible*
I	Perinatal	0	0
II	Before or during early primary dentition	+	0
III	Later primary dentition	++	+
IV	Mixed dentition	++	++

At the occlusal crest of the alveolar bone in both the maxilla and mandible, a more rapid-growing type of bone tissue occurs in relation to tooth eruption and the vertical drifting of the teeth. As in Stage III, thin, small spot deposits of periosteal lamellar bone continue to provide cover on localized surface bulges overlying protruding roots or crowns of erupting teeth.

Discussion

The timing for the first appearance and subsequent spread of the anterior maxillary and mandibular resorptive fields is summarized in Table I. Note that the mandible lags in both regards. Surface resorption is entirely lacking in both the maxilla and mandible throughout postnatal Stage I (as well as throughout the entire prenatal period). During Stage II resorption appears in the maxilla but not in the mandible. In Stage III a near-maximum extent of surface resorption has been established for many of the maxillary specimens but has just begun in the mandible. By the mixed dentition period the full development of the outer-surface remodeling pattern is present in all of the specimens, both for the maxilla and mandible.

Thus, the time of reversal from the prenatal and perinatal periods of surface deposition to the postnatal occurrence of surface resorption *begins* shortly after birth in the maxilla and is followed in the mandible before complete eruption of the primary dentition. These resorptive fields then spread progressively. At the time of reversal the *anterior* direction of growth elongation of the bony alveolar arches is concluded (except for small increases at the alveolar crests incident to incisor eruption). Thereafter, maxillary and mandibular horizontal lengthening occurs almost entirely in posterior directions in conjunction with the process of anteroinferior displacement.[6] Before the time of reversal the anterior surfaces of the alveolar arches are composed of fast-growing, fine-cancellous bone tissue (as in the fetus) providing for continuing arch expansion and elongation in conjunction with the enlarging tooth buds.

As described by Schour and Massler,[13] the permanent first molars begin to form and calcify at about birth. The permanent anterior teeth then begin their major period of formation at four to six months postnatal. The late infancy period from six months to about one year is characterized by eruption of the deciduous incisors. The crowns and roots of the other teeth are simultaneously enlarging preparatory to eruption. As shown by Sillman,[12] the greatest increase in the posteroanterior dimension of the arches mesial to the canines occurs from birth to two years. From two to six years there is little or no significant addition. Moorrees and Reed[11] demonstrated that no significant increase in posteroanterior arch length takes place during the six to twelve year period. These observations indicate that the anterior parts of both the maxilla and mandible are not required to increase in anteroposterior size after completion of the primary dentition and our findings provide supporting histological and morphogenic evidence.

It has been shown by implant studies that the course of human maxillary growth is essentially straight downward[1,2] during the period subsequent to the reversal reported in the present study. The large resorptive remodeling field, covering most of the anterior face of the maxilla, relates directly to the vertical mode of maxillary growth because of the concave and outward-sloping contour of the external maxillary surface.[6] Because the outer maxillary surface points essentially upward, it must necessarily be resorptive (together with endosteal bone deposition) for the maxillary bony arch to grow straight downward. If a given individual's arch actually decreases in horizontal length as a result of the presence of the leeway space,[8] this resorptive anterior surface also provides the remodeling basis for such a change. Further, if an alteration in axial inclination of the permanent incisors is involved, as described by Fastlich,[7] the resorptive pattern of surface remodeling already in operation can accommodate this circumstance.

The possible reason for the characteristic lag in the timing and spread of the mandibular reversal as compared with the maxillary reversal is not clear, although two factors appear to be involved. First, the maxilla grows in a much closer association with the faster and earlier-growing anterior endocranial fossae than the mandible. The maxilla is directly contiguous with the anterior part of the basicranium and linked to it by sutural growth sites. Second, the growth of the maxillary complex involves the growth expansion of the nasal region, and the marked downward-forward bony remodeling of the palate is linked directly to this circumstance and must accommodate it. An early and significant extent of downward remodeling thus must be carried out for the maxillary bony arches. As pointed out above, this requires a surface field of resorption in the anterior part of the maxilla. In contrast, most of the vertical growth movement for the mandibular arch is provided by the enlarging ramus.

Variations in the distribution, configuration and size of these resorptive fields relate to the topographic characteristics of the different individual specimens. Just as wide variation is seen in the shape and outline of the resorptive fields, corresponding extents of variation occur in surface morphology of the whole bones themselves. A skull, for example, that has a deep concavity in the infraorbital part of the maxilla will show a broad field of surface resorption covering this whole area (Fig. 3). Other specimens having a bulging convexity in this same infraorbital region, in contrast, show a surface that is of a depository rather than a resorptive nature.

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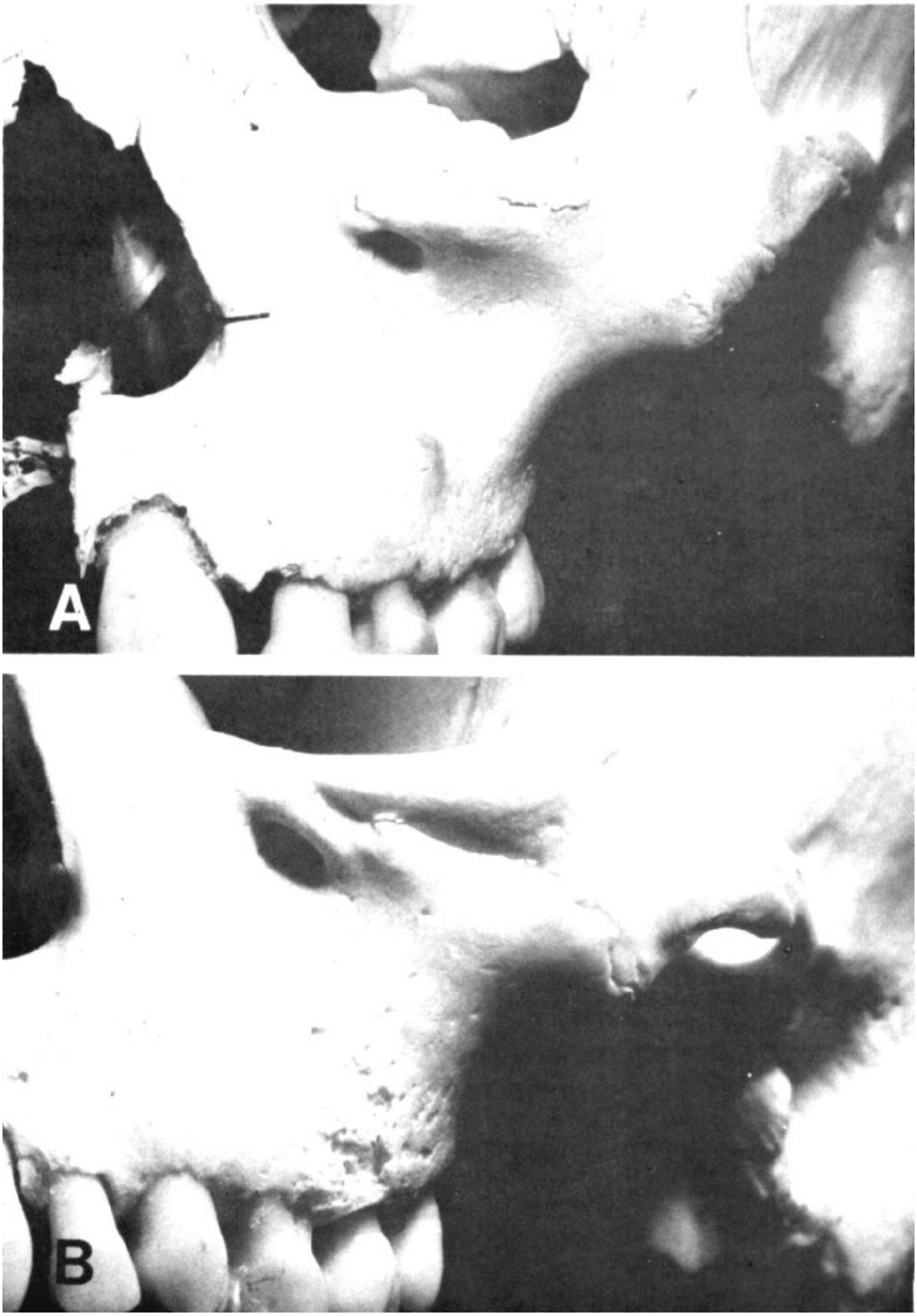

Fig. 3 In specimen No. 29 (Fig. 1), the sizable field of resorption relates to the much more concave nature of the maxillary surface in the infraorbital region (A). In specimen No. 31, the more convex topography in the same region relates to a much lesser extent of surface resorption (B).

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