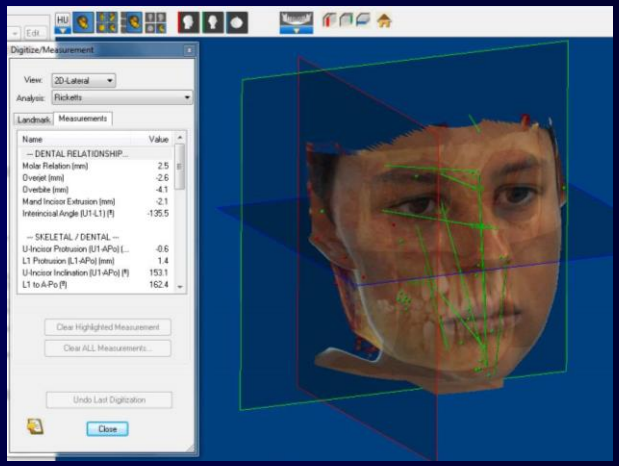
31-year-old female patient with severe skeletal and dental Class III malocclusion and unilateral crossbite before treatment.

Remarks to the morfology of skull and jaw over time

Structure and function
Morphological dissection followed by other methodological approaches helps to explain the proces of the formation and trends

AIM:
to relate selected structures of external morphology to the principles of postnatal formation

Other examples and discussions in the autopsy room

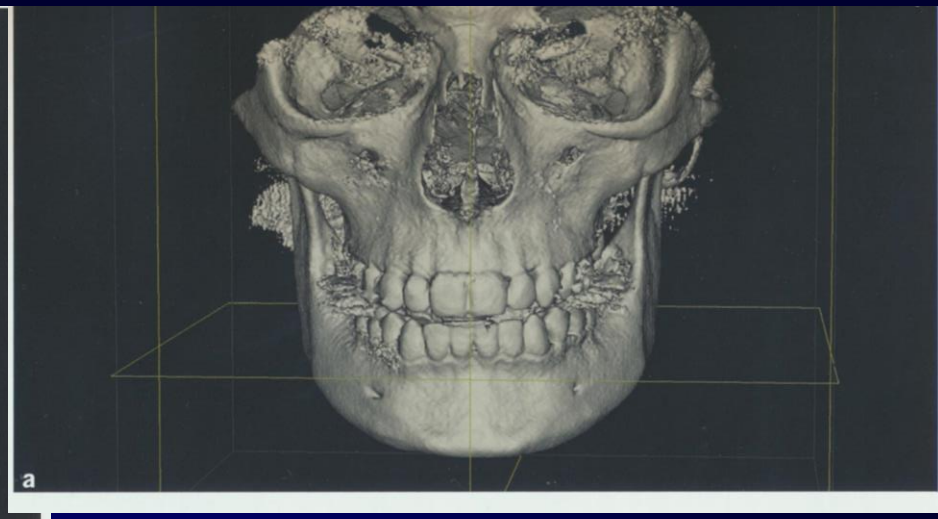


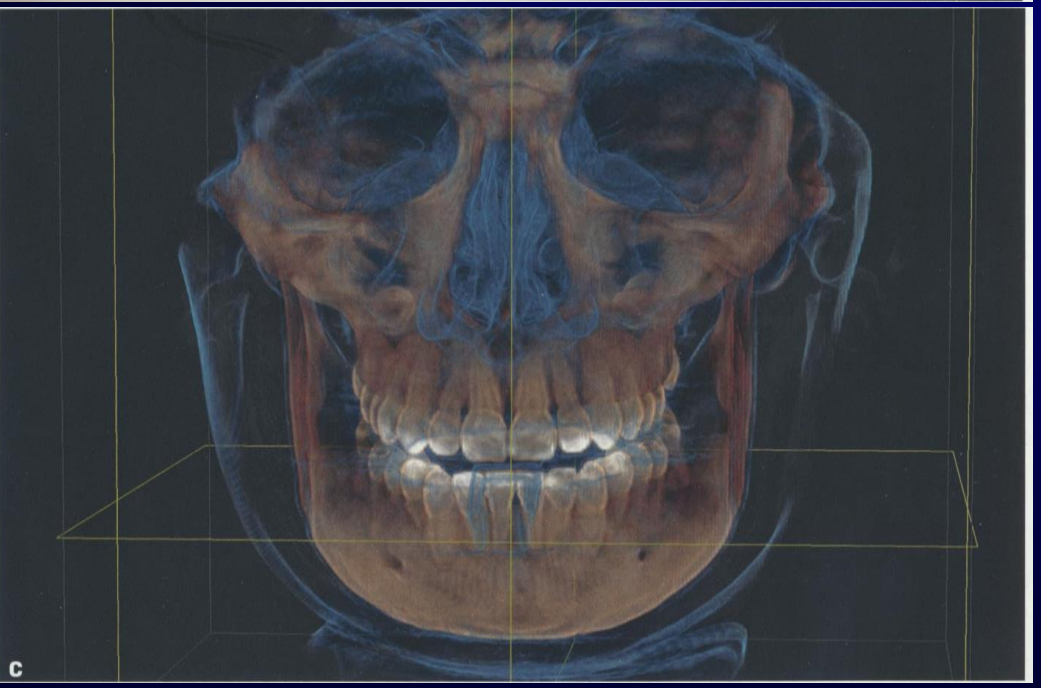
Ortopanoramatické snímky v závislosti na věku

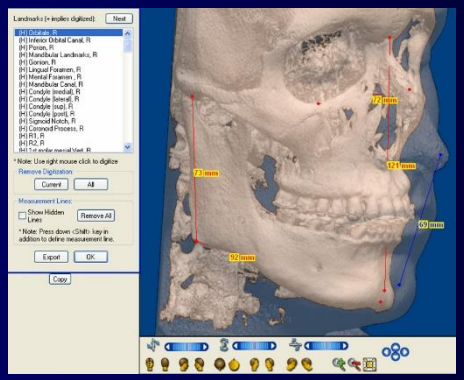
OPG photos related to age

Formation of the skeleton of the face, thickened and weakened areas of the skull.

Ivo Klepáček



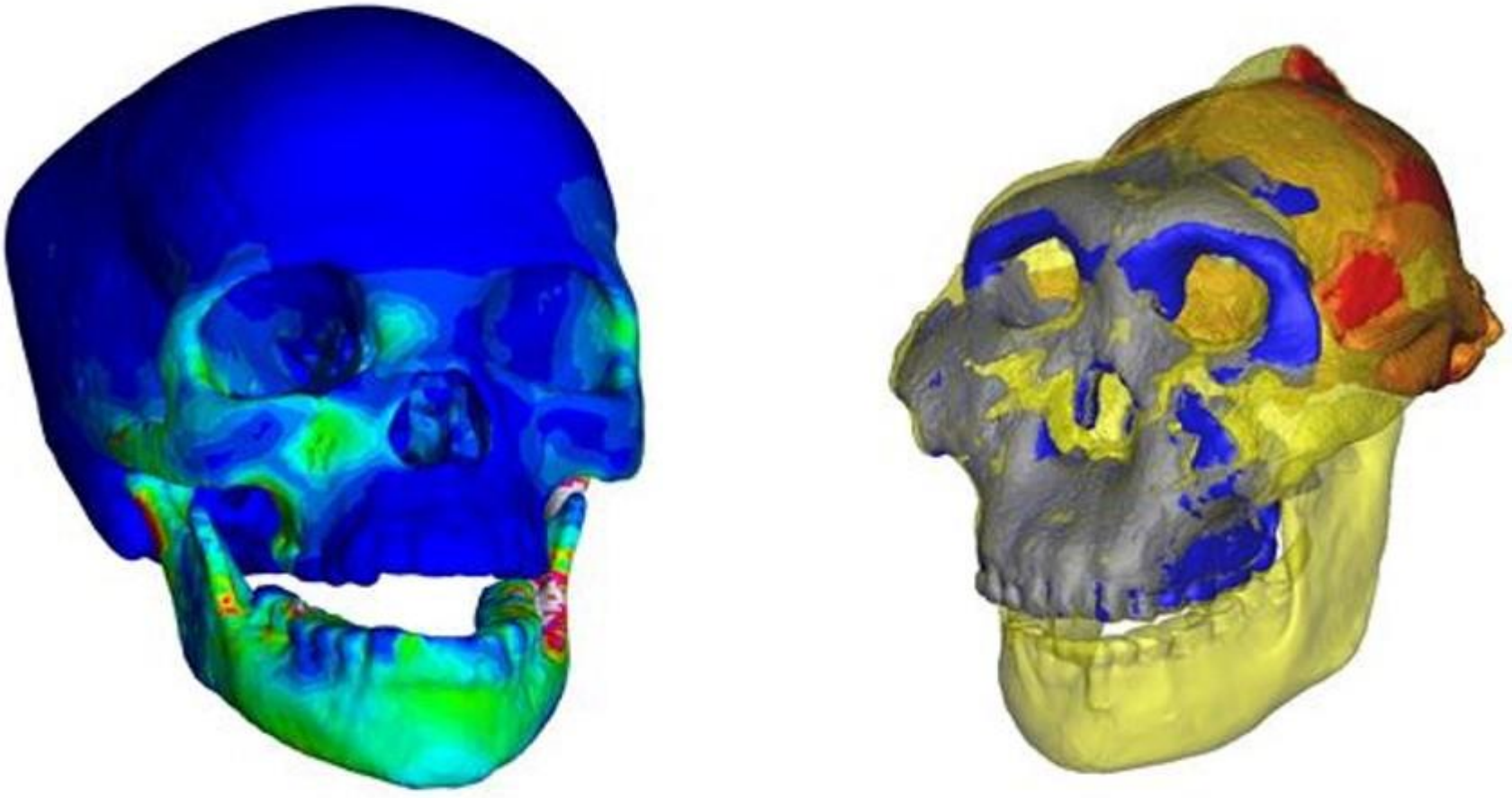




Tři zobrazení dat získaných kuželovým paprskem: a) povrchová metoda, b) objemová metoda, c) s vizualizací měkkých tkání

Three depiction of cone-beam volume data: a) surface-based method, b) volume-based method, c) with soft tissue visualization

Fig 1-16 A 3D depiction of cone-beam volume data: (a) surface-based method; volume-based method (b) without and (c) with soft tissue visualization.

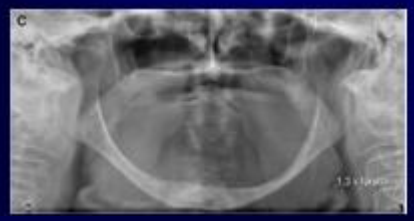


These images of a human and early human (*Paranthropus boisei*) skulls allowed scientists to compare bite forces.

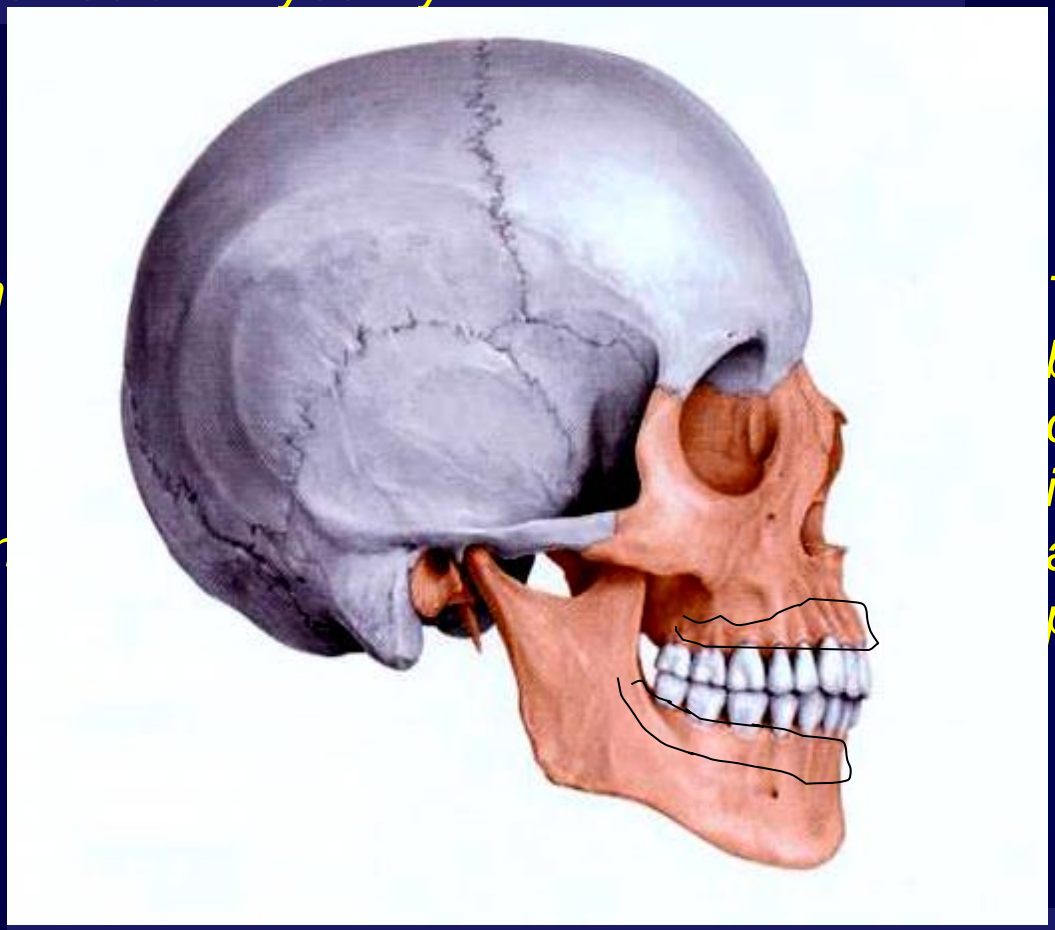
Červené oblasti - místa zatěžovaná při žvýkání -
lebka opice je více zatěžovaná tlakem a tahem ve spánkové krajině
Srovnání lebky moderního člověka a předchůdce člověka

Red areas - places most stressed by mastication –
The early human (as a monkey skull) is more burdened by pressure in the temporal region
the monkey's skull and human ancestor are compared

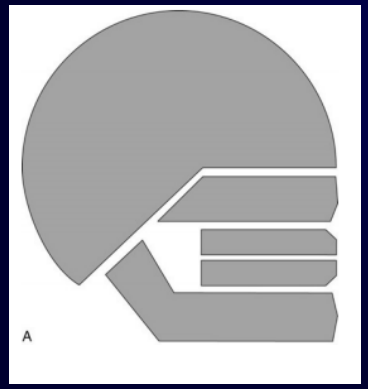
- *1 Lebeční base*
- *2 Tělo maxily a nasozygomaxilární komplex*
- *3 Tělo dolní čelisti*
- *4,5 Zuby a alveolární výběžky*



Vzájemný vztah uvedených komponent v zadopřední a vertikální rovin



The relationship between these components in the postero-anterior and vertical planes



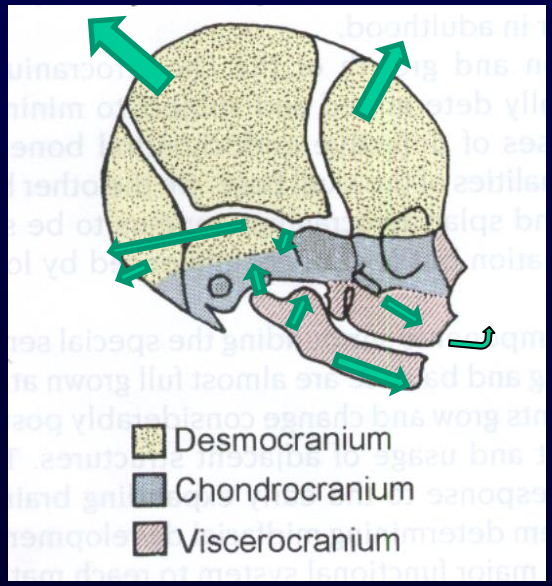
- ***1 Cranial base***
- ***2 Skeletal maxila and nasozygomaxilary komplex***
- ***3 Skeletal mandible***
- *4,5 Teeth and alveolar processes*

Postnatal formation of the skull. Male and female skulls.

*The so-called **cranial growth** is a type of growth, when in about 6 years the size of a given trait is reached (slow pubertal spurt),eg. cerebellum and orbit facial growth (appropriate spurt), in 6 years about 80 percent of the size of the final feature is reached – eg. zygomatic-maxillary, nasozygomatic-maxillary complex and the dorsal part of the cranial base lengthens.*

The basis of developmental formation and compensation is growth.
Proportional, shape and positional changes are the result.
It is uneven, accelerating during periods of so-called spurts.

Skull vault (calvaria,cap) ! ? !
skull basis
facial skeleton
maxila mandible

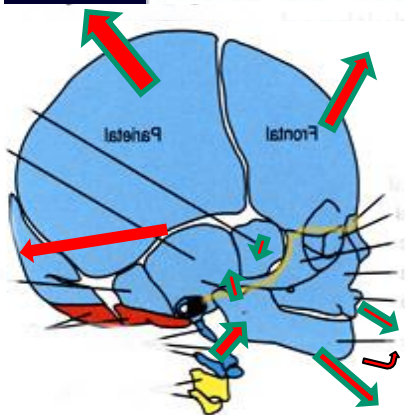


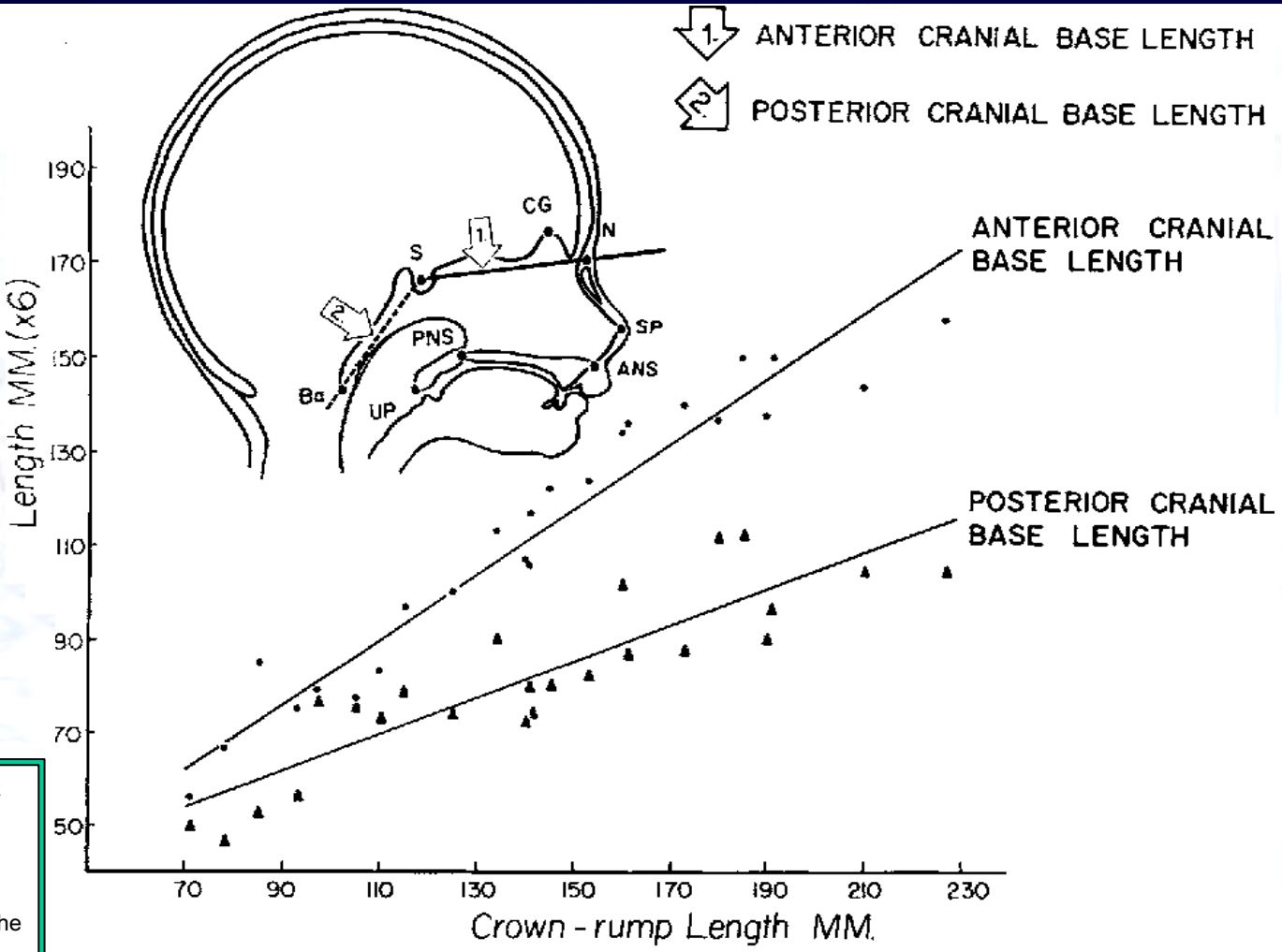
Features following changes in skull form

Brain enlargement; synchondrosis sphenooccipitalis ossification; eye bulb and orbit enlargements, muscle tractions; nasal septum growth; growth nasal,zygomatic and maxillary bones+tooth eruptions

Growth types:

neral – to 70% final size 6 yr
anial – to 80% final size 6 yr
cial – to 80% final size 6 yr





Comprehensive growth of the skull - enlargement of the cerebellum 1-4 years
Splanchnocranium grows more intensively after 6 years (teeth)
Characters - intensive growth of the ramus mandibulae - the vertical relations of the jaws of the anteriorotation decrease, the inclination of the palate does not change, the palate descends caudally and the verticality of the face does not change much

34 Weeks

Skull basis changes with age

1 yr os frontale (squama + sinus frontalis ↑)

4 yr cribriform lamina of ethmoidal bone

7 yr spheno-ethmoid,-frontal; fronto-sphenoid

resorptive areae – around lacerum foramen, jugular fossa, medial lamina of pterygoid process

Order of structures involved in activities:

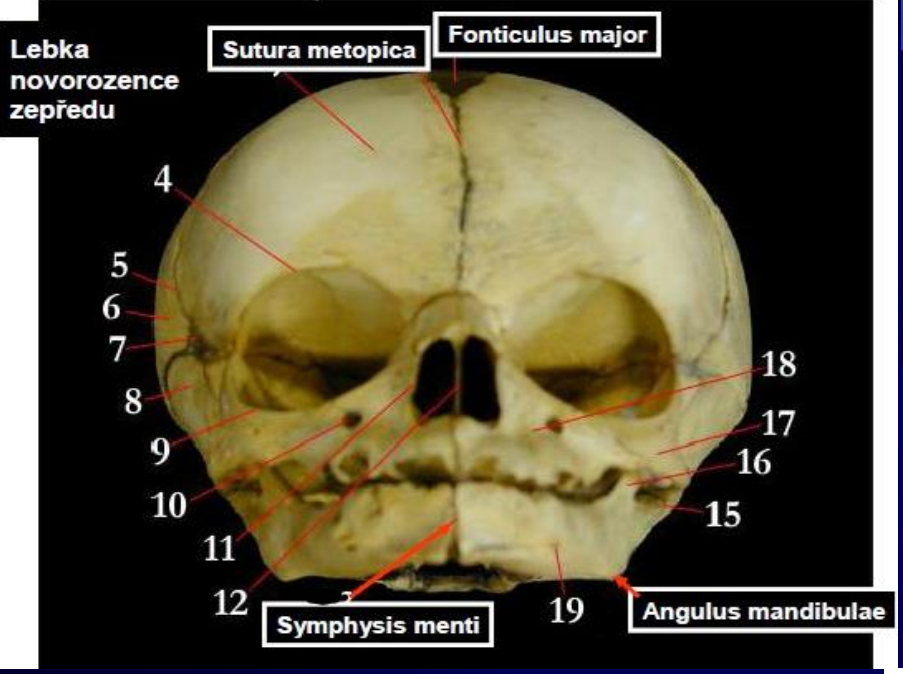
nazozygomaxillar complex – from sutures surrounding maxilla

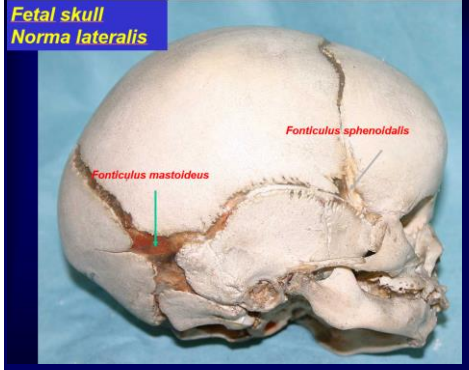
infrazygomatic crest –

sutura palatina transversa

after Enlow 1968

Sedý 2013





Synchondrosy přední base mizí kolem 6 roku

Synchondroses in ventral skull basis are missing about year 6

Zadní baze roste ze sutury do 16 let

Dorsal skull basis is growing from the suture to 16 year

Kloubní jamka se objeví kolem 2,5-3 roku
Condylar fossa appears about 2,5-3 year

Newborn skull

Big neurocranium

Small splanchnocranium; facial skeleton

Frontal and parietal tubercles are prominenting (ossification starts)

Cranial fontanells; fonticles

Paranasal cavities are not developed

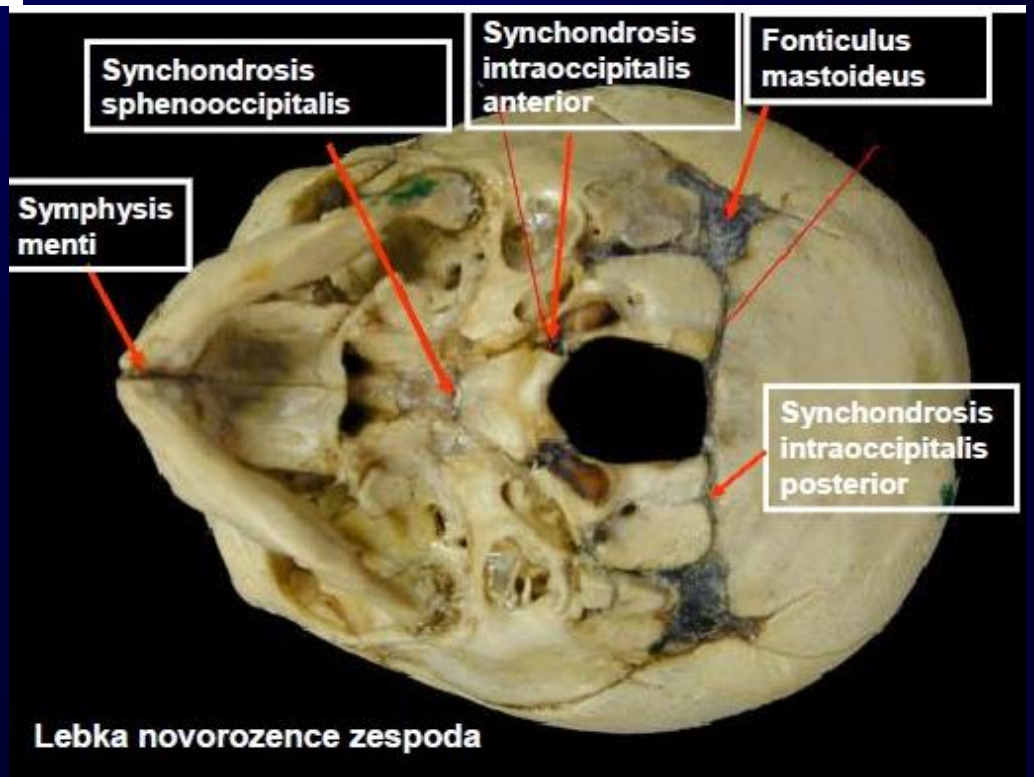
Metopis suture can be visible

Suture between maxilla and premaxilla is present

Symphysis menti

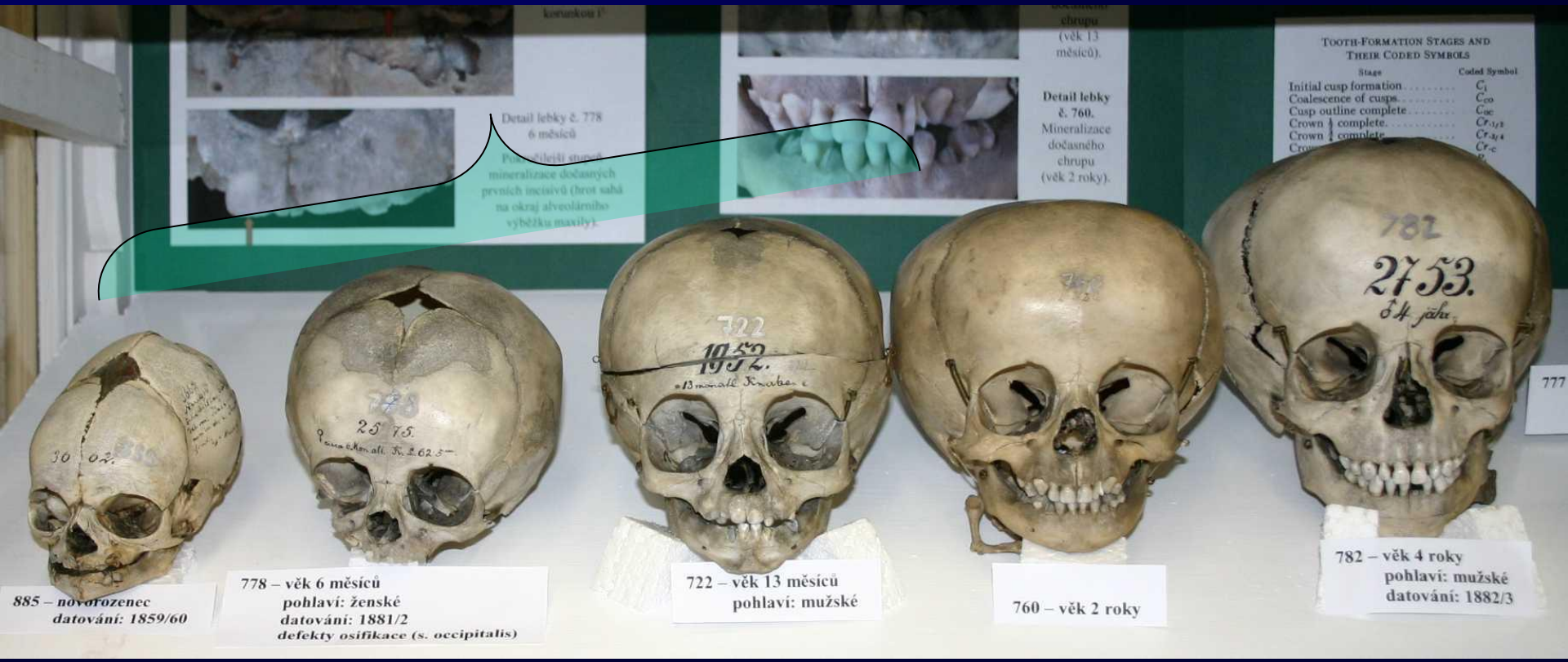
Mandibular angle - 150-160°

Tympanic bone is like a semicircle



Newborn skull exhibits typical proportions: brain part (neurocranium) is larger in comparison with face part (splanchnocranium).

An individual features are noted - orbital arches, dimensions of the orbital entrance and the shape of the aperture piriformis
Intensive growth of the neurocranium is still in 1-2 years - clamp, The main growth process in the skull is during the first five years facial growth accelerates later due to tooth eruption; the ramus mandibulae increases

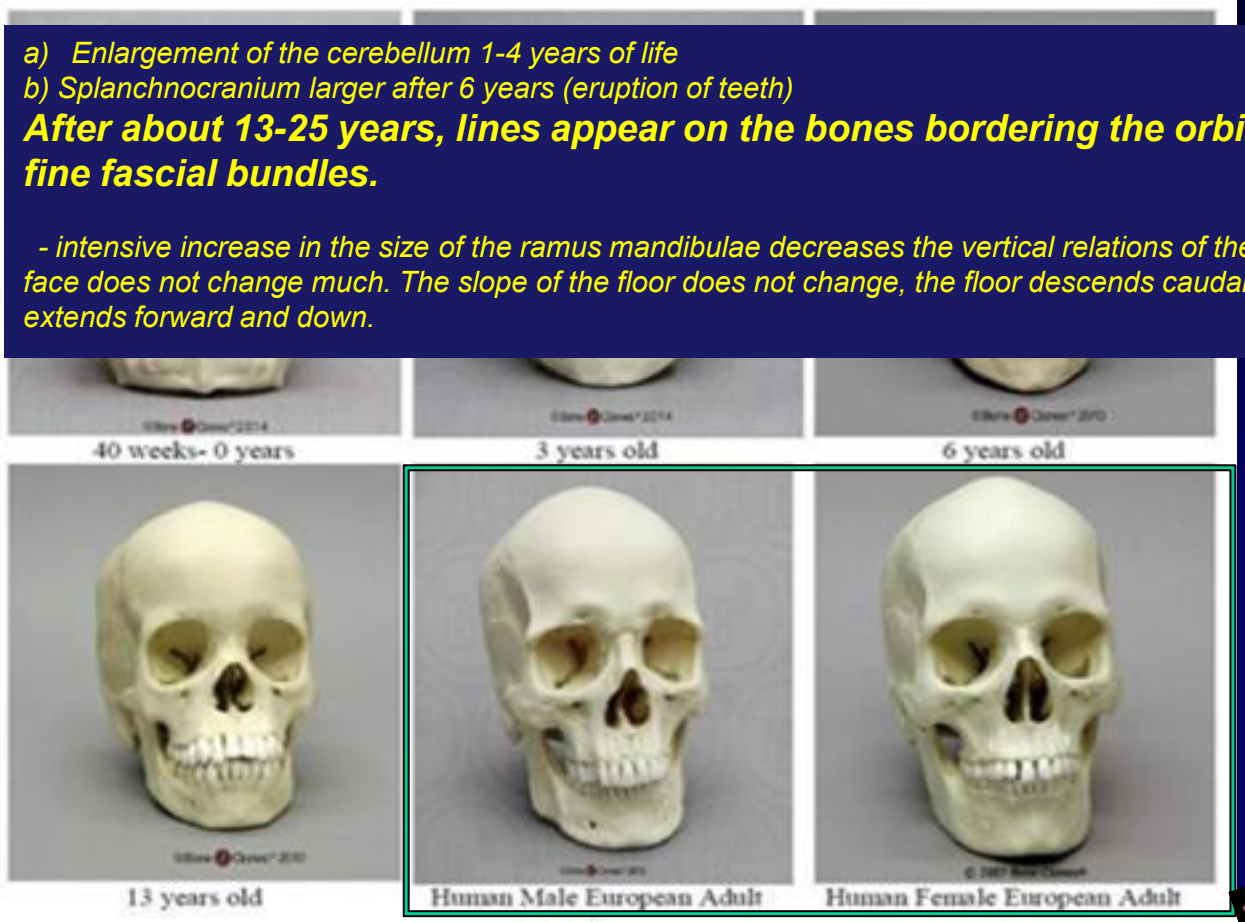


Anatomical institute LF 1 UK; museum

a) Enlargement of the cerebellum 1-4 years of life
b) Splanchnocranium larger after 6 years (eruption of teeth)

After about 13-25 years, lines appear on the bones bordering the orbit - the places of attachment of fine fascial bundles.

- intensive increase in the size of the ramus mandibulae decreases the vertical relations of the jaws - anteriorotation the vertical of the face does not change much. The slope of the floor does not change, the floor descends caudally The nasozygomaxillary complex extends forward and down.

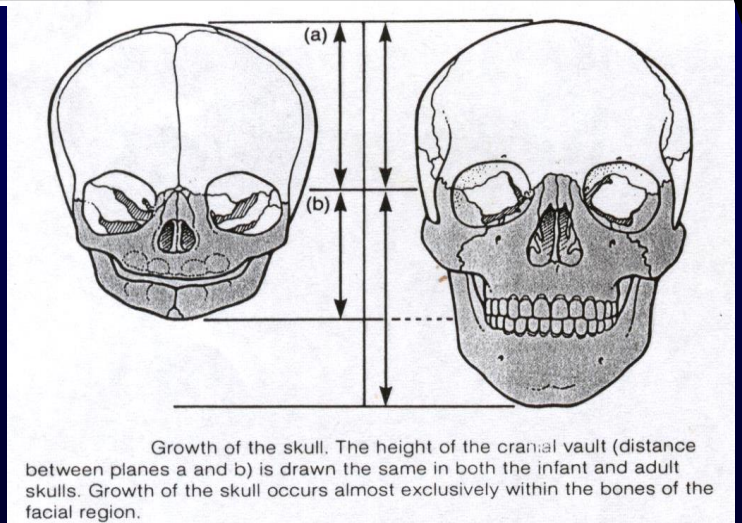


face width - starts to growth earlier

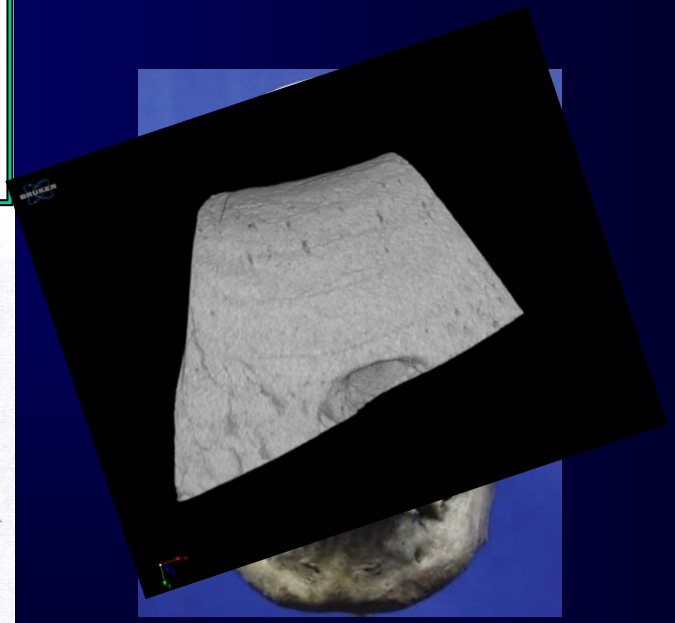
face length – *finish to growth later*

Between year 6-18 the face width in boys enlarges about 21 mm; in girls only about 18 mm

Height dimensions change the most, width the least



Growth of the skull. The height of the cranial vault (distance between planes a and b) is drawn the same in both the infant and adult skulls. Growth of the skull occurs almost exclusively within the bones of the facial region.



Neurocranium ... growth spurt ... during first two years

The proportions of the skulls from the newborn to the adult and senile skulls. Notable changes:

The maxilla - ***the resorption area*** *is below the apertura piriformis; from birth it spreads over the entire area of the bone*

The mandible - ***the resorption area*** *arises above the protuberantia mentalis from the age of 2 and does not spread too much.*

Typical of humans - Protuberance continues to grow

Comprehensive growth of the skull *- enlargement of the cerebellum 1-4 years*

Characters - posterior rotation of the vault of the cerebellum (dorsal displacement of the bregma, vertex points),

Apposition in the area of protuberantia occipitalis posterior *– long time*

Splanchnocranium *grows intensively after 6 years (teeth)*

Characters - intensive growth of the ramus mandibulae - the vertical relations of the jaws of the anteriorotation decrease, the inclination of the palate does not change, the palate descends caudally and the verticality of the face does not change much

fast. The low face is caused by small jaws and low alveolar protrusions

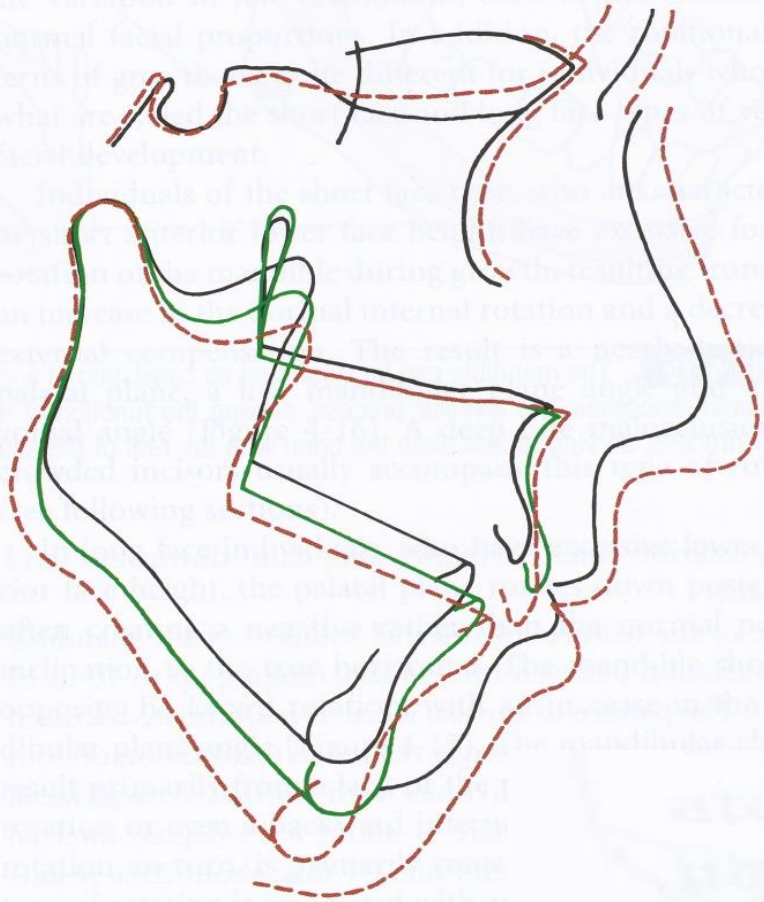


FIGURE 4-17 The pattern of jaw rotation in an individual with the "long face" pattern of growth (cranial base superimposition). As the mandible rotates backward, anterior face height increases, there is a tendency toward anterior open bite, and the incisors are thrust forward relative to the mandible. (From Björk A, Skieller V. Eur J Orthod 5:29, 1983.)

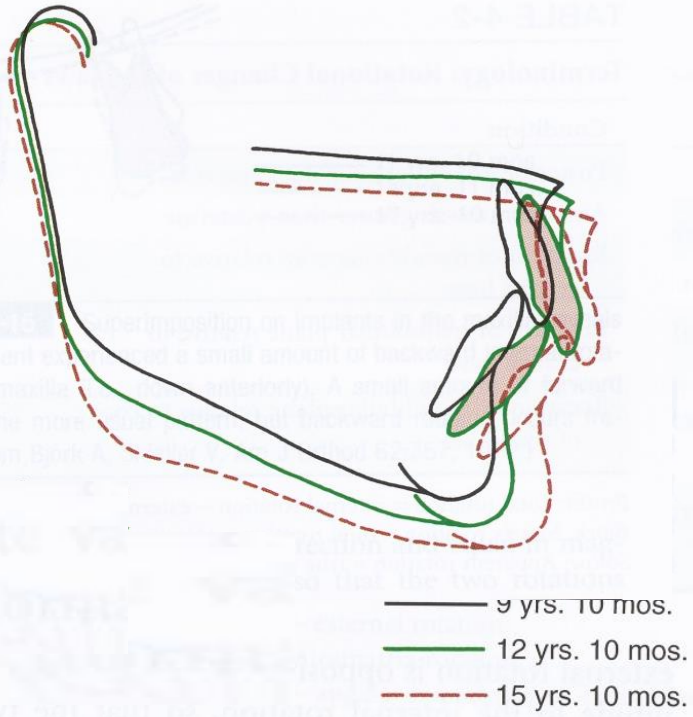


FIGURE 4-16 Cranial base superimposition shows the character-
pattern of forward mandibular rotation in an individual developing
e "short face" pattern. The forward rotation flattens the mandibular
e and tends to increase overbite. (From Björk A, Skieller V. Am J
od 62:344, 1972.)

Mandibula rotuje vpřed, zvyšuje se předkus
Krátký obličej

superpozice lebeční báze

Mandibula rotuje nazad otevřený skus
Řezáky směřují vpřed, dlouhý obličej

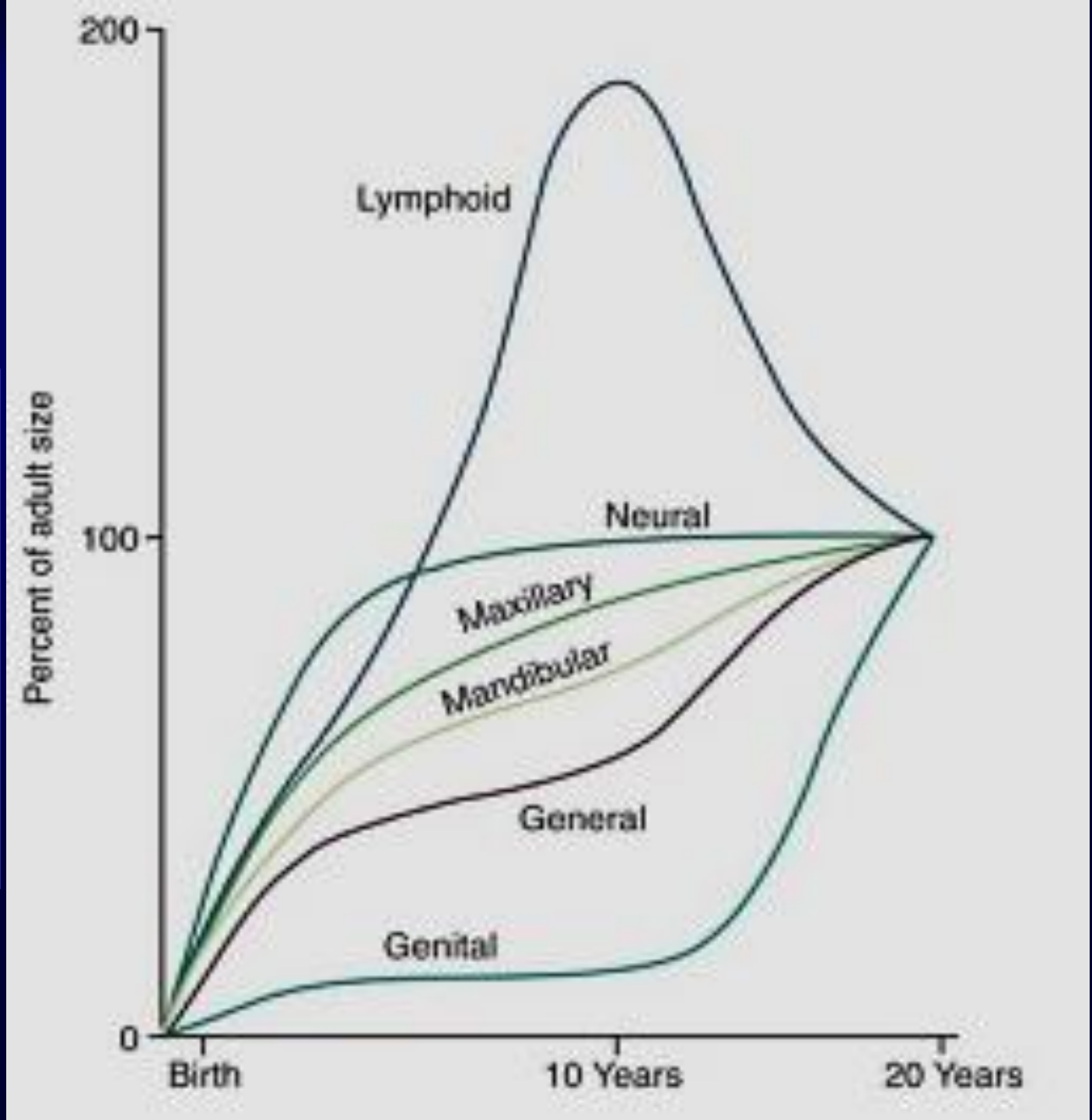
Růst growth

The growth curve of the jaws compared to other organs is relatively steadily increasing with age.

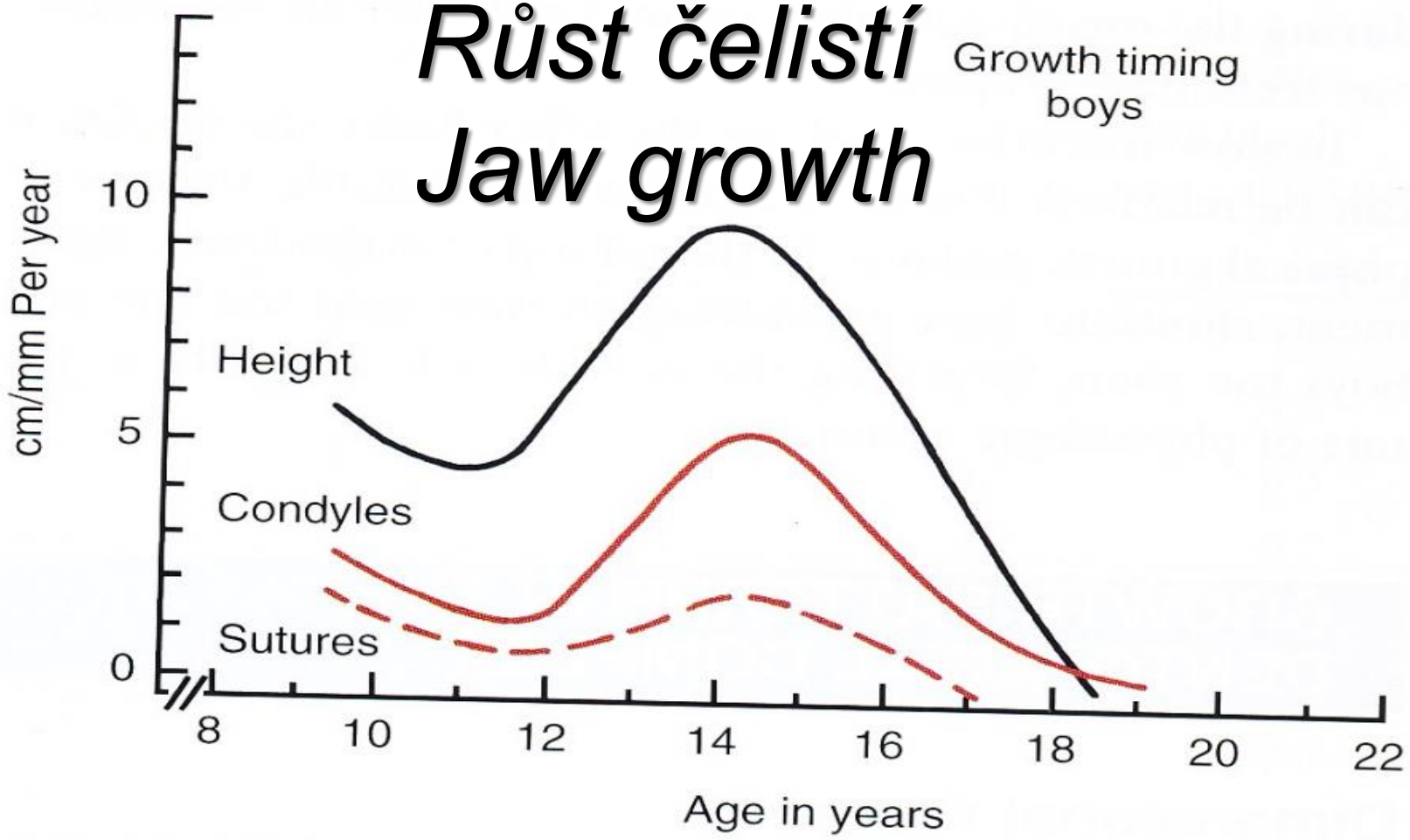
An adolescent growth spurt occur on the average nearly 2 years earlier in girls than in boys

Acceleration of jaw growth in youth is reported to be approximately consistent with weight gain. *Growth is influenced by ethnic, type, nutritional and social civilization conditions*

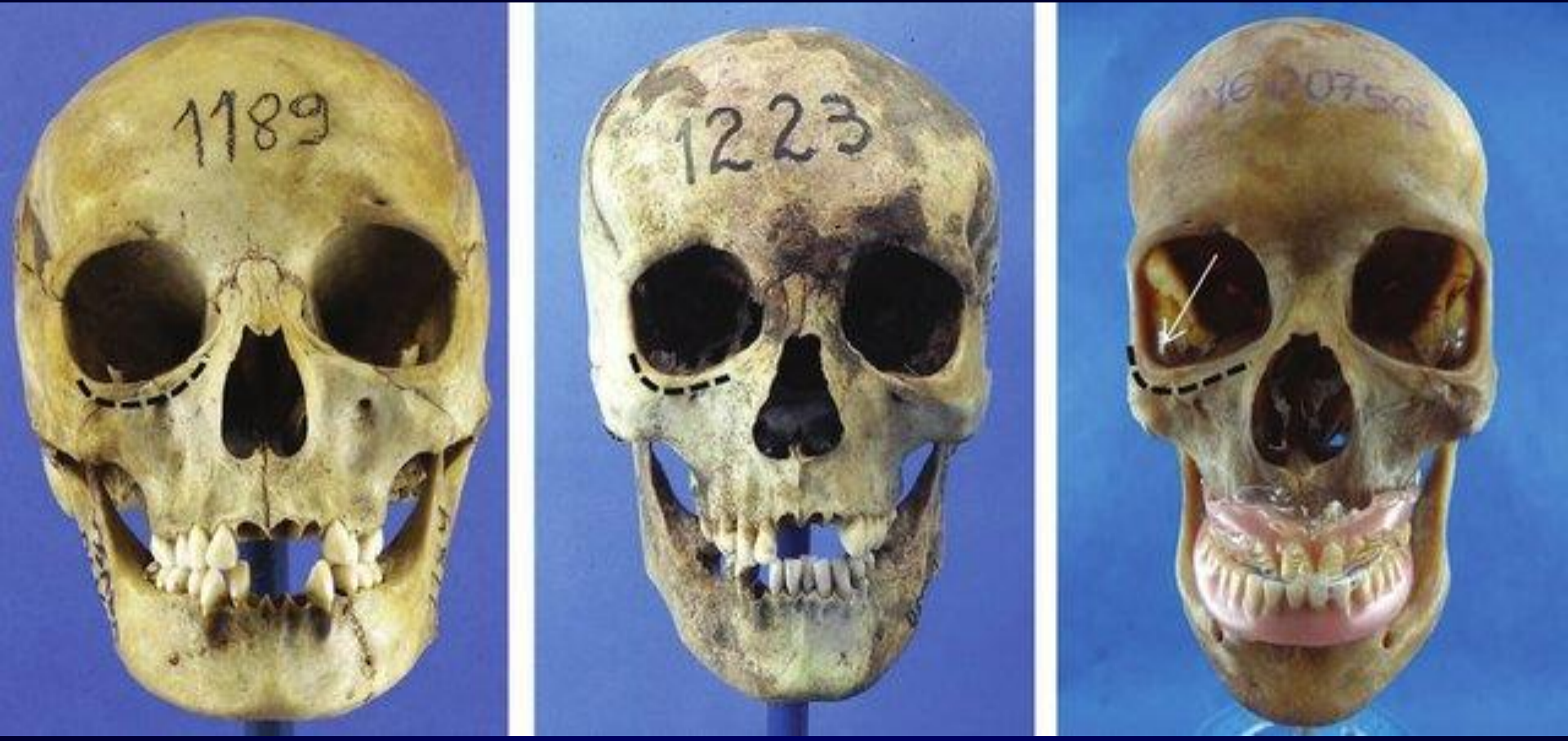
Před pubertou
Before puberty



Růst čelistí
Jaw growth

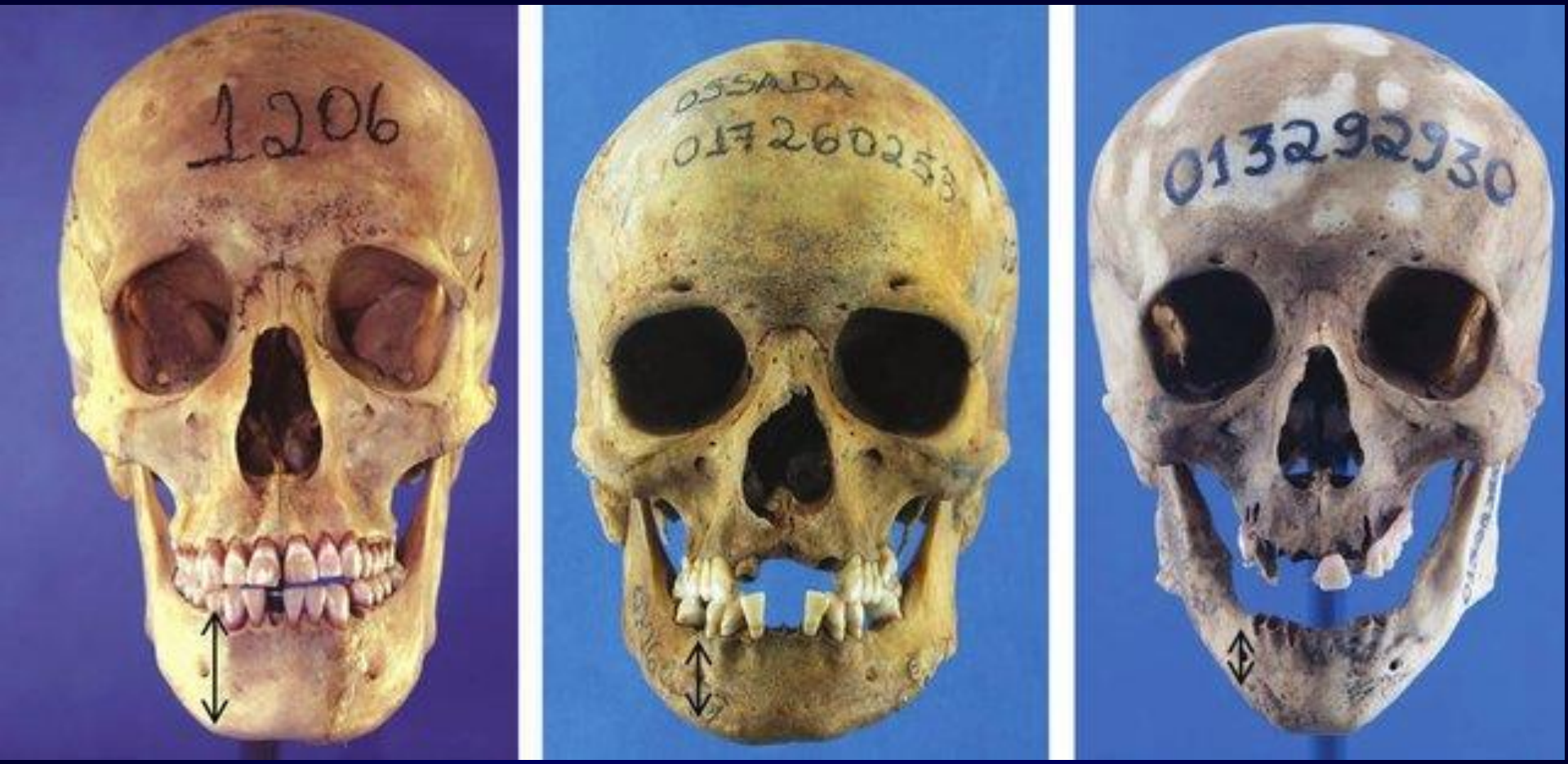


růst čelistí v průměru zrychluje ve stejnou dobu jako se zvyšuje váha; ale existují individuální variace



Orbit and piriform aperture.

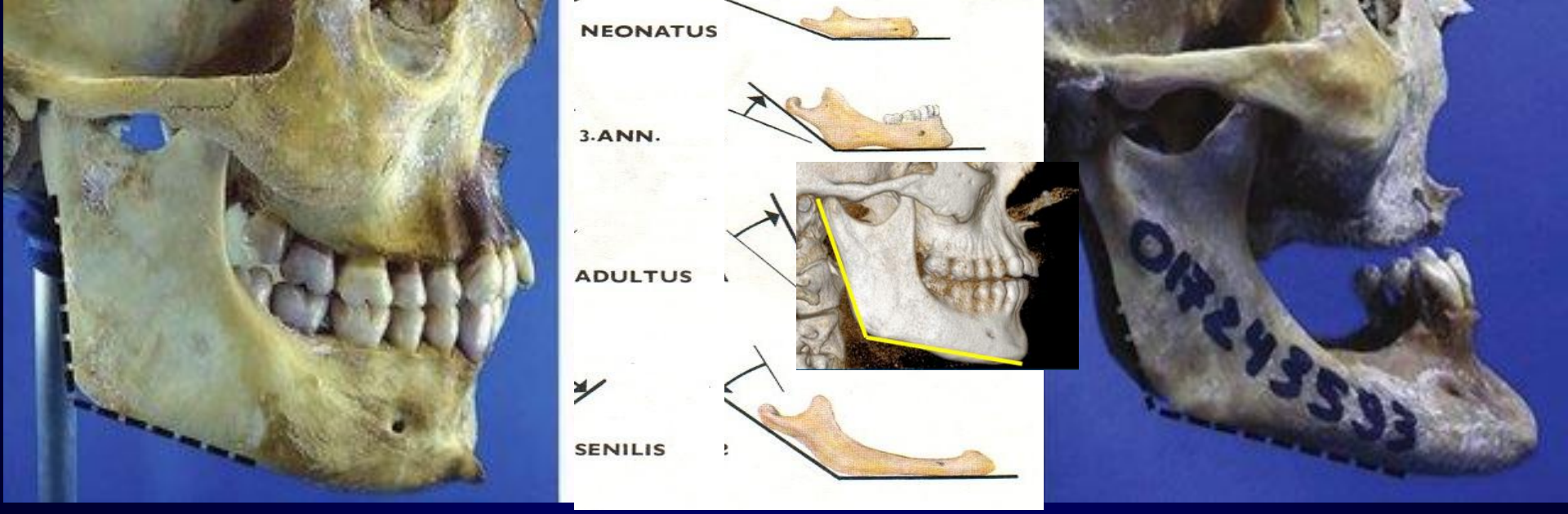
the rounded orbit shape initially increases its size, while maintaining the shape. later the latero-inferior border presents a more pronounced resorption. the maximum measurement of piriform aperture increases with aging, being prominent in skulls >50 years.



Maxilla + mandibula.

Maxilární resorbce se zvyšuje *s věkem; snižuje se o*bsah tuku v kůži a množství kolagenu. To vede k sestupu měkkých tkání ve střední etáži. Čelisti s přibývajícím věkem ztrácejí výšku a jsou křehčí.

there is an increase in maxillary resorption with aging, which is associated with decrease in skin fat and collagen contents and leads to midface soft-tissue descent. also, with increasing age, the mandible loses its vertical projection and is more fragile.

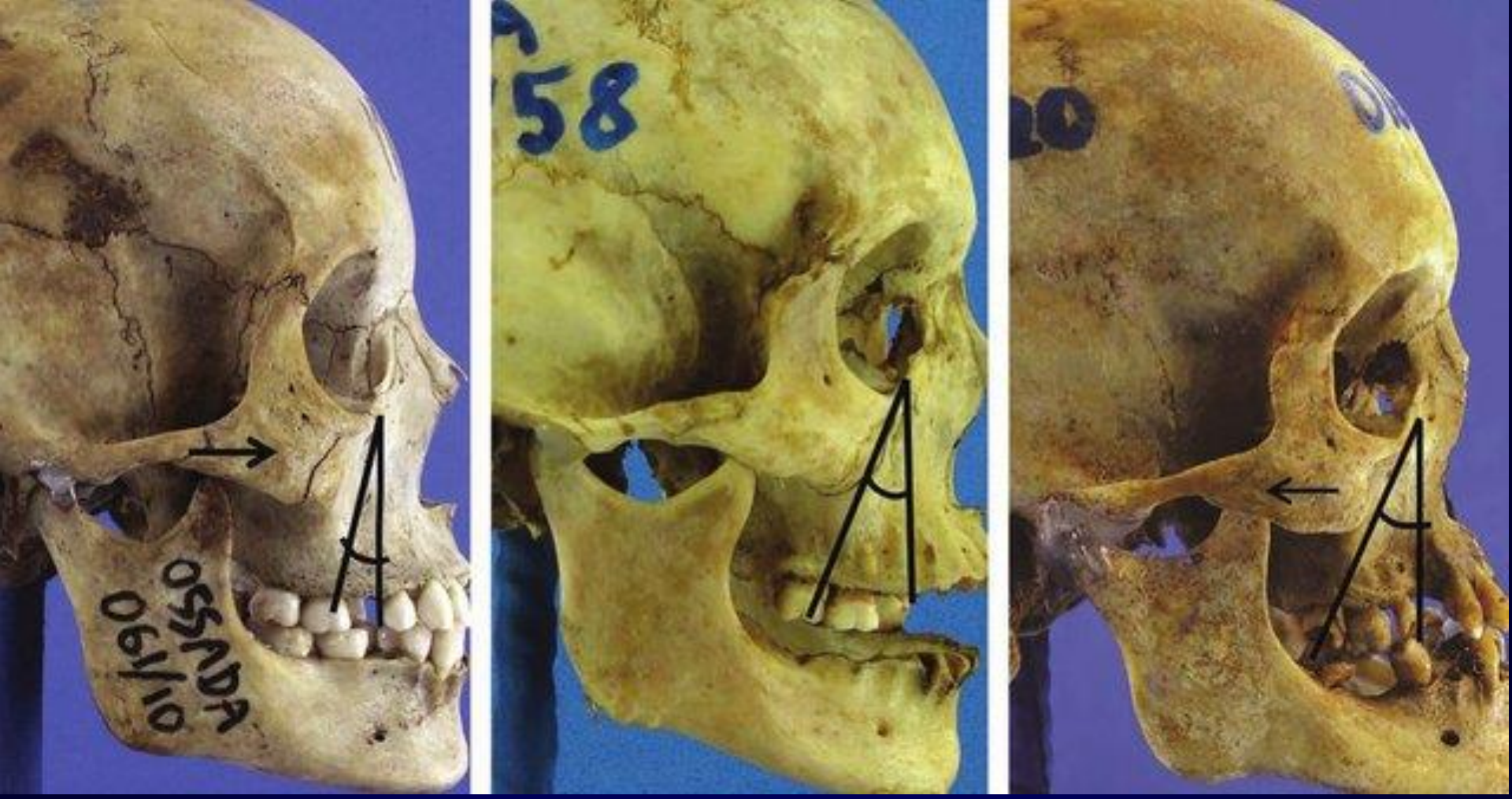


Mandibula a brada

Mandible angle and chin.

v mladším věku je úhel ostřejší (u mužů 97 stupňů), s přibývajícím věkem (135 stupňů) se stává rozevřený a brada se v důsledku remodelaci kostí stává šikmější a kratší.

at younger age, the angle is acute (in males 97 degrees), becoming more obtuse with increasing age (135 degrees), and the chin, with bone remodeling, becomes more oblique and shorter, with increased anterior projection.



Zygoma.

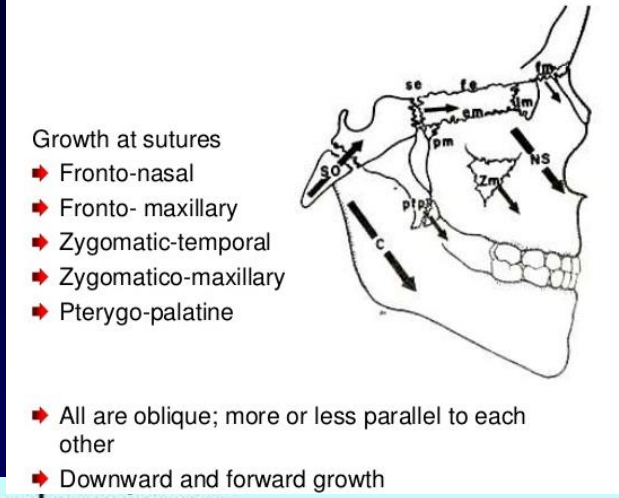
Considering the skull in anatomic position, the zygoma becomes more retropositioned with aging, with an increasing angle between an imaginary vertical line and the anterior border of the zygoma.

´nasozygomaxilární´ komplex
´nasozygomaxillary´ complex

Changes in form in this area depends on two mechanisms:

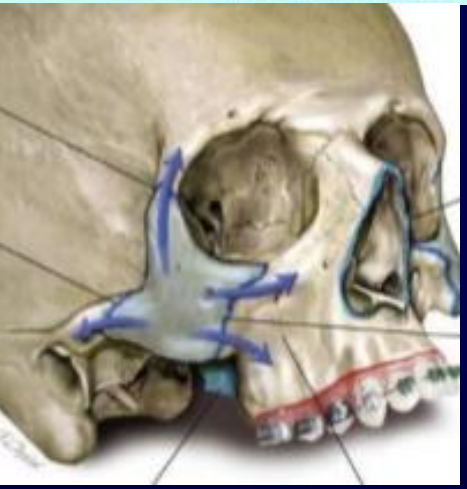
Pasivní posun *horní čelisti vpřed v důsledku růstu lebeční base*

Aktivní růst *struktur horní čelisti a nosu*

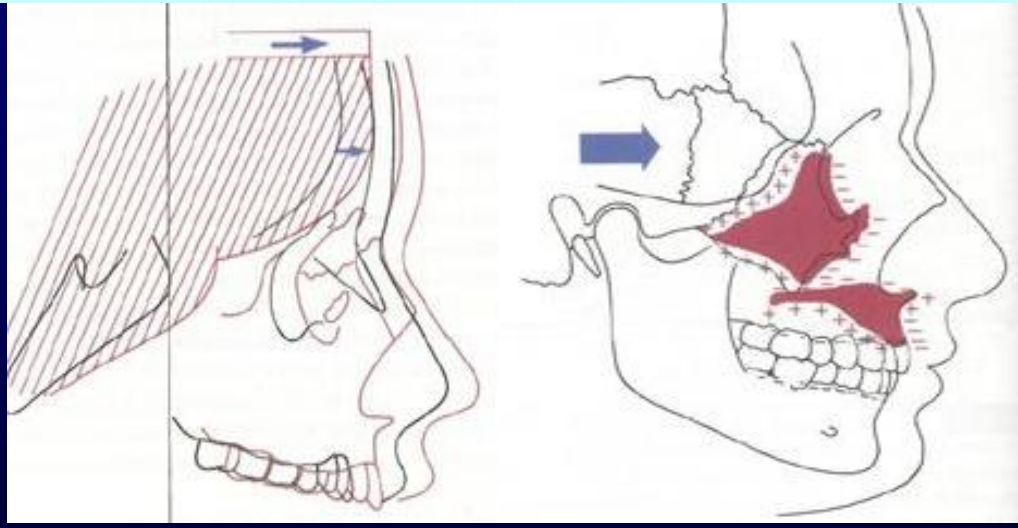


– Growth of this area produced by two basic mechanisms

Sutures determine ventrocaudal growth.
Resorption of the ventral surface of the maxilla; apposition on the dorsal surface of the zygomaticum os.
Because the ventral area of the maxilla resorption does not increase with age - protrusion of the upper jaw and prominence of the nasal bones.

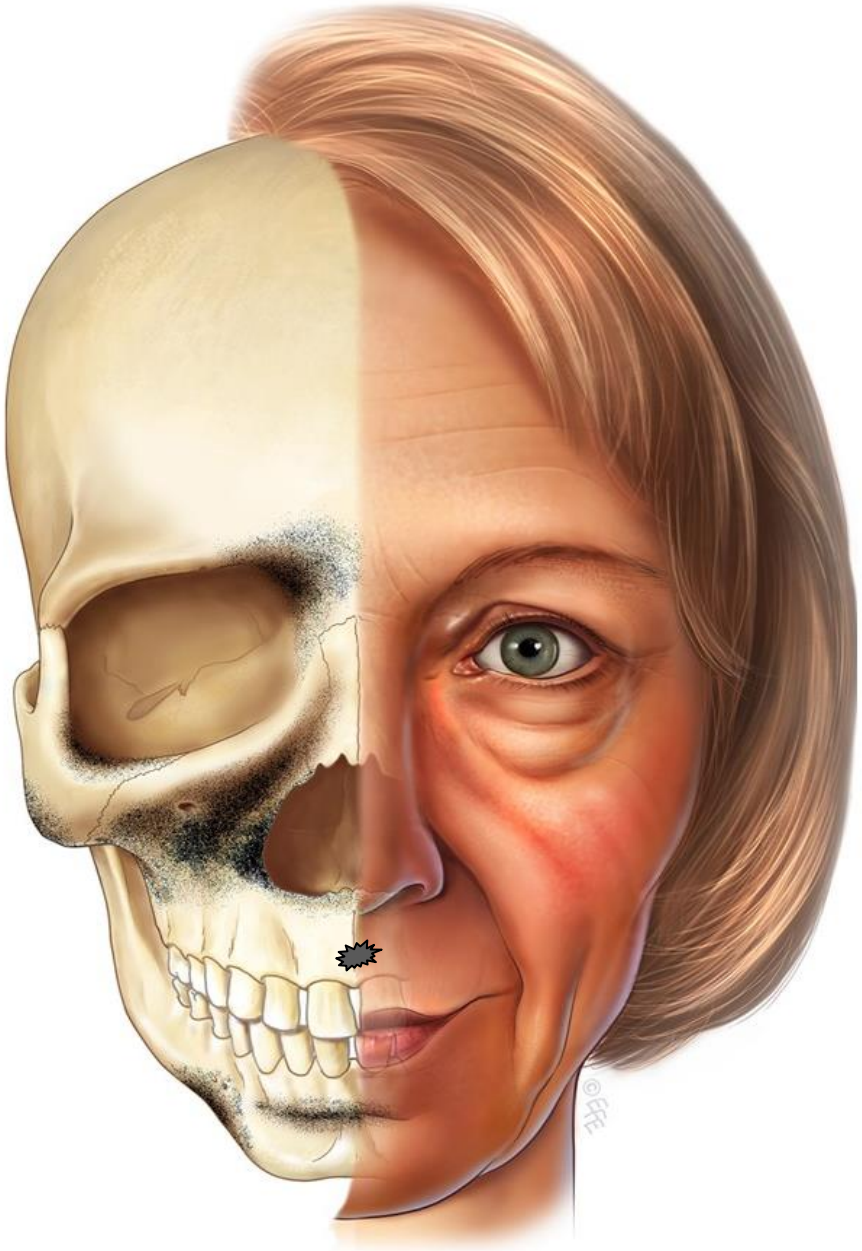


Expanze švů mezi lícní kostí, kostí čelní, spánkovou a maxilou



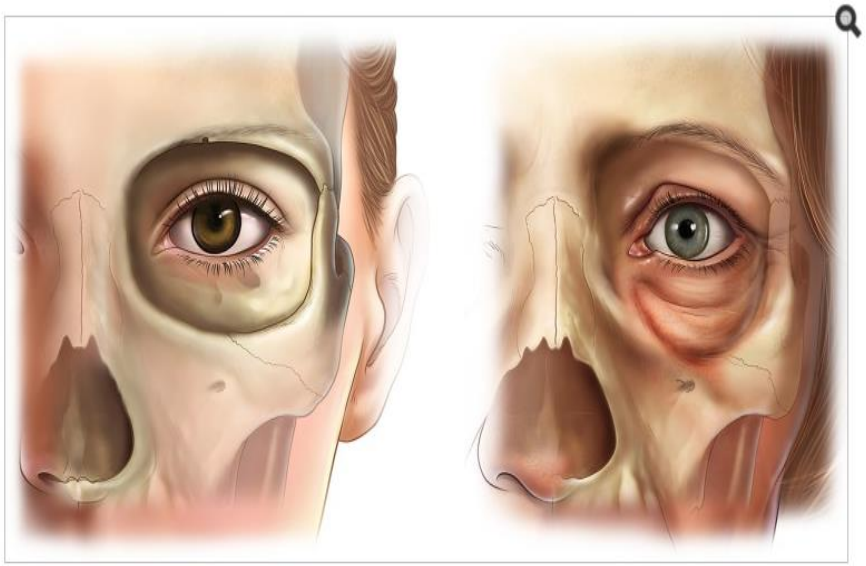
Expansion follows sutures: zygomaticomaxillary, zygomaticofrontal (frontozygomatica), zygomaticotemporal, frontomaxillary

Fig. 6



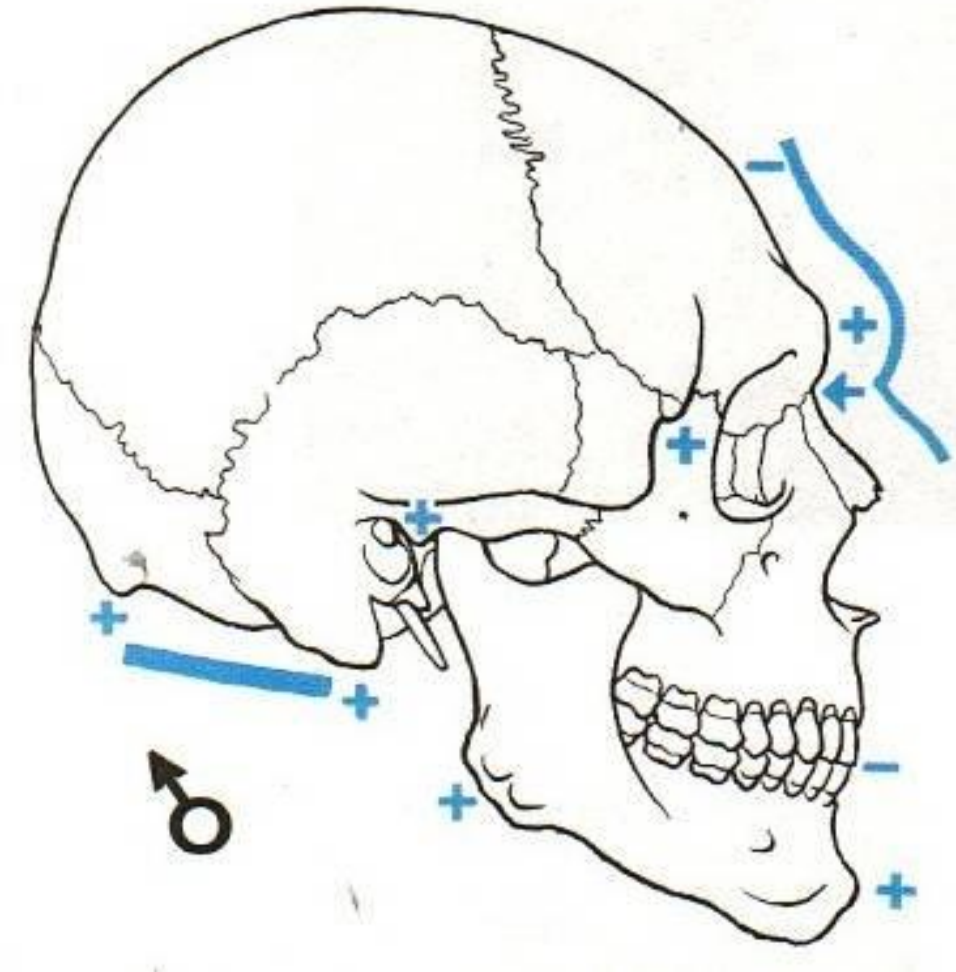
The *darker areas* are those of the greatest bone loss. The stigmata of aging, manifested by the facial soft tissues, corresponds with the areas of weakened skeletal support

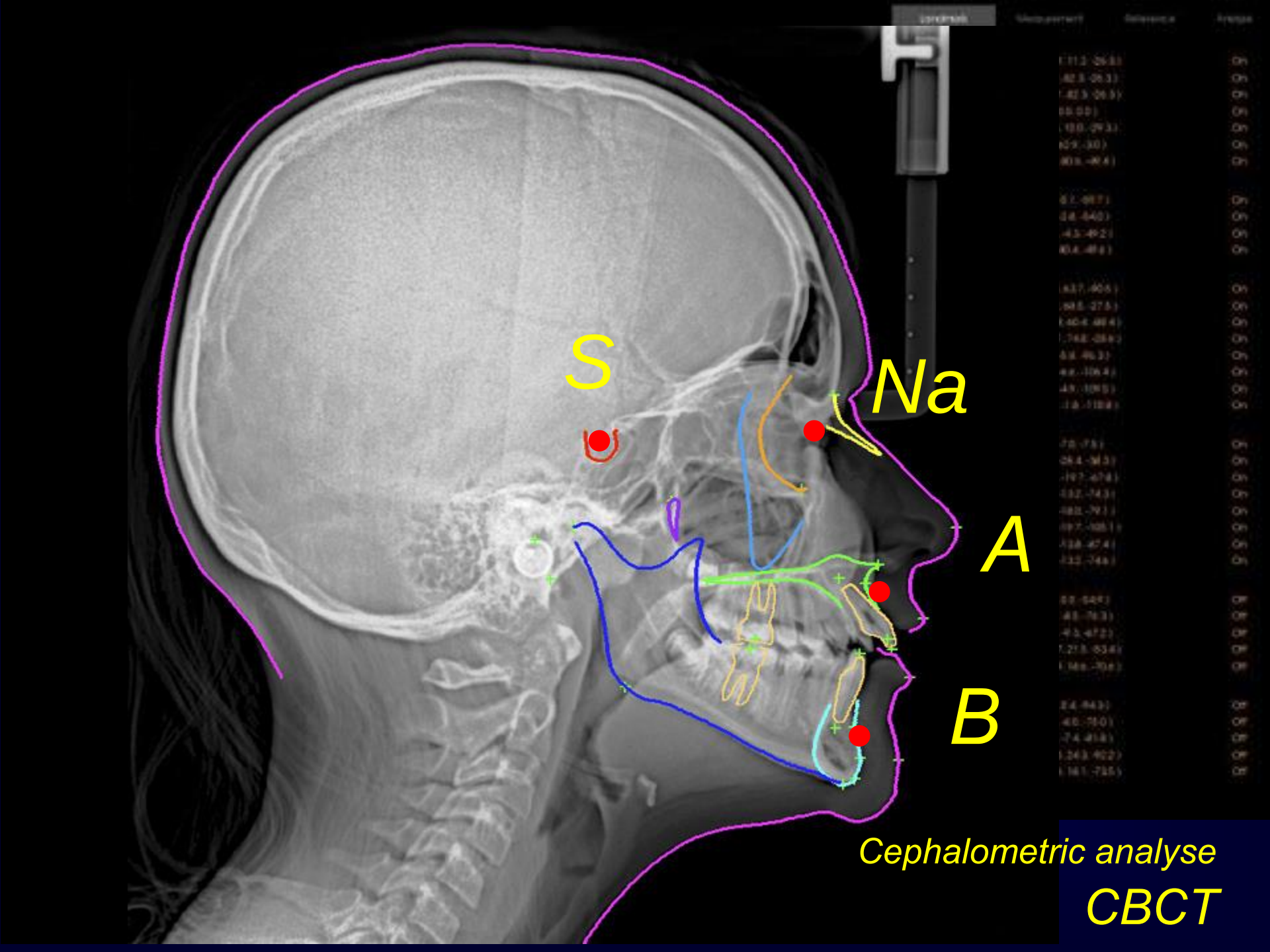
Fig. 1



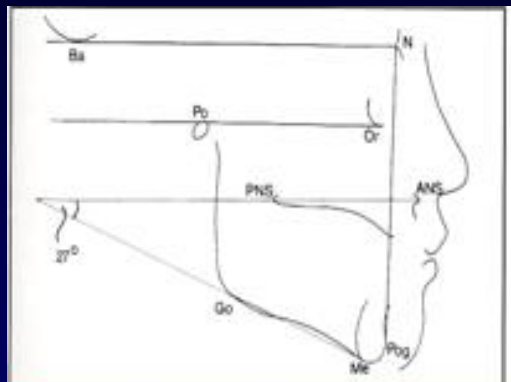
Orbital aging. The superomedial and inferolateral aspects of the orbit have the greatest tendency to resorb. This contributes to the stigmata of periorbital aging such as increased prominence of the medial fat pad, elevation of the medial brow, and lengthening of the lid cheek junction

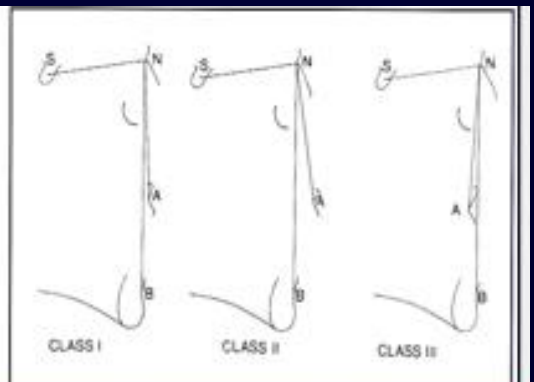
Gender differences between skulls male and female




S
Na
A
B
Cephalometric analyse
CBCT

According to the size of the ANB angle, the skeletal class is evaluated, in which, similarly to the classification of occlusion. The basis of classification is the ventrodorsal relationship:





Měření	Norma	Zvětšený	Zmenšený	Poznámky
S-N-A	81°	prognátní HČ	retrognátní HČ	
S-N-B	79°	prognátní DČ	retrognátní DČ	
A-N-B	2°	skeletální II. třída	skeletální III. třída (ANB < 0°)	závislé na SNMeGo (viz str. 138)

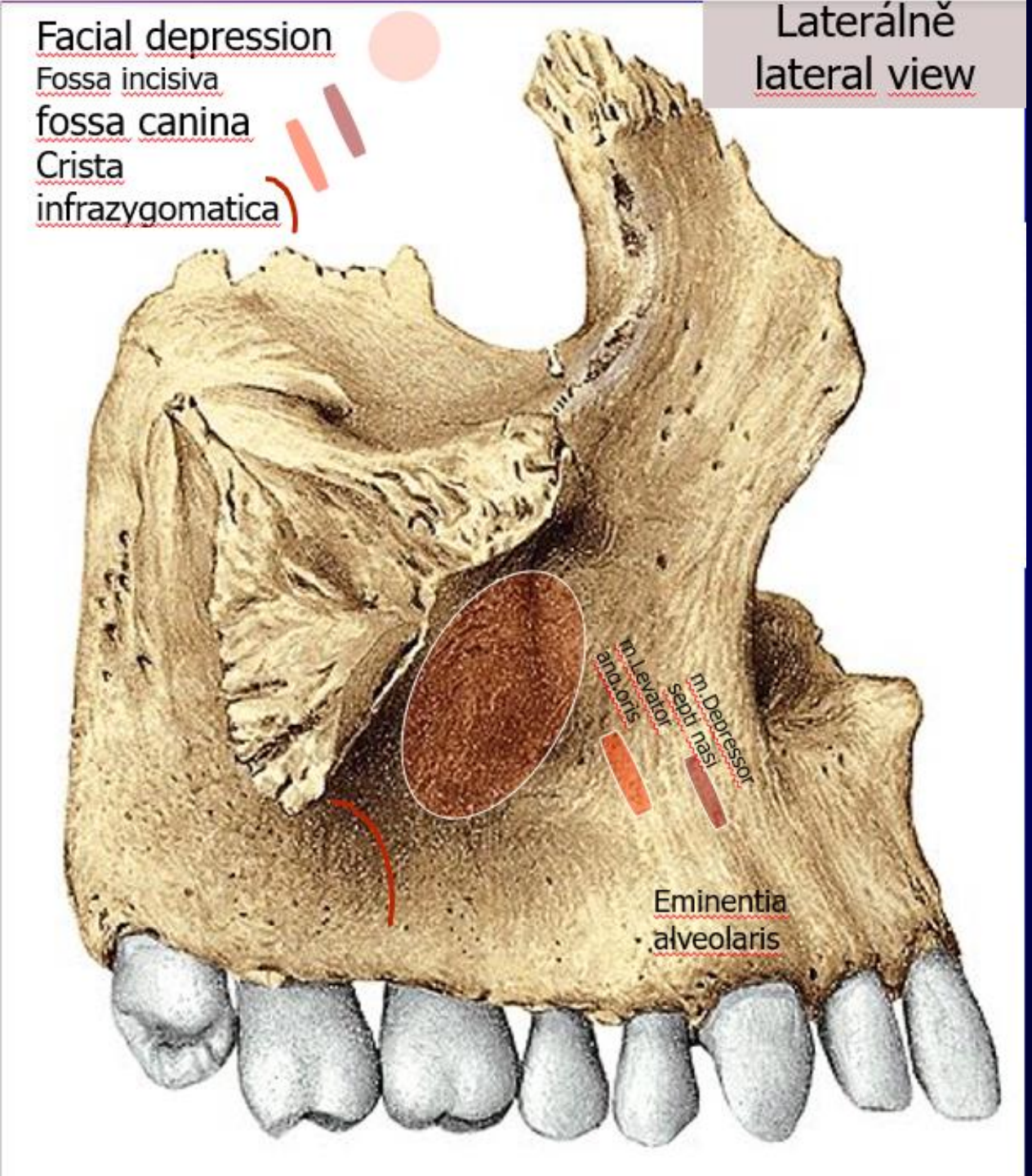
I. skeletal class *- ie the average relationship of the jaws without significant deviation. ANB = -1 ° to + 5 °*

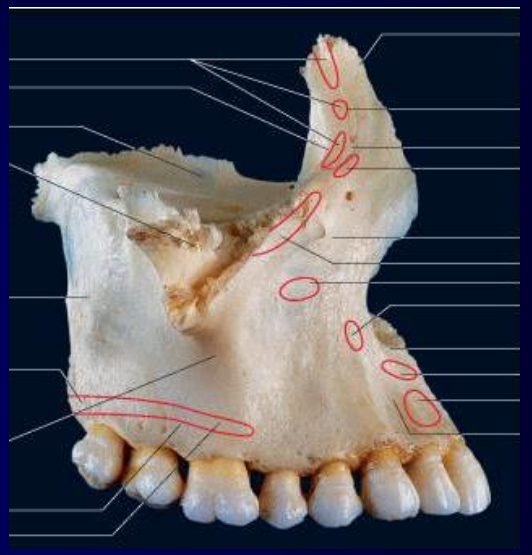
II. skeletal class *- the mandible is relatively dorsally shifted to the maxilla. ANB> + 5 °*

III. skeletal class *- the mandible is relatively ventrally shifted to the maxilla. ANB <-1 °*

after Thaller, S.R., Bradley, J.P., Garri, J.I.: Craniofacial Surgery. Informa Healthcare USA, New York 2008, 395

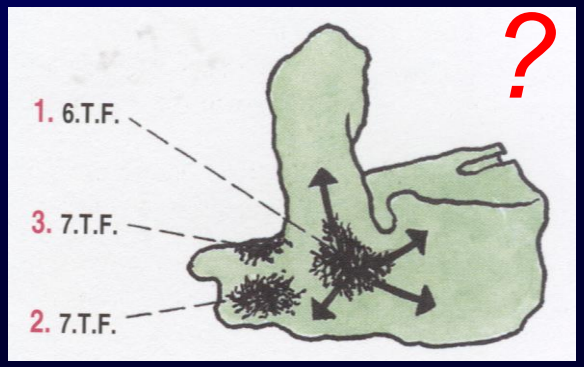
Maxilla





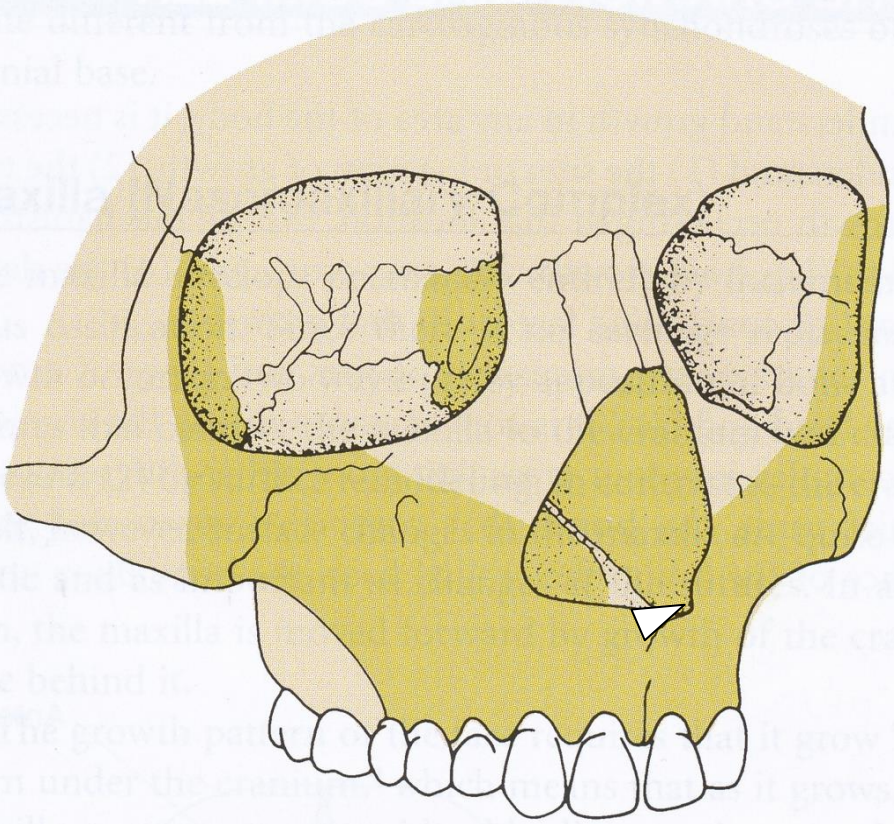
Depressed area:

Infrazygomatic seu infraorbital fossa

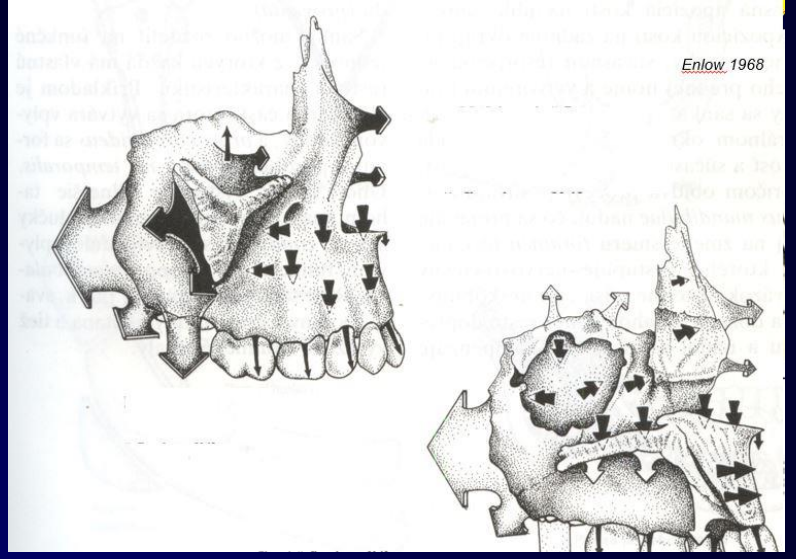


Foramen rotundum
N. maxillaris
Ganglion trigeminale
R. meningeus
Rr. ganglionares ad ganglion pterygopalatinum
Ganglion pterygo-palatinum
Nn. alveolares superiores posteriores
Fissura orbitalis inferior
R. communicans
N. zygomaticus
N. infraorbitalis
N. alveolaris superior medius
Rr. alveolares superiores anteriores

Canalis ´sinuosus´ Parinaud´s can.
Canalis superior anterior



anterior surface tends to resorb. Resorption surfaces are shown here in dark yellow. Only a small area around the anterior nasal spine is an exception. (Redrawn from Enlow DH, Hans MG. Essentials of Facial Growth. Philadelphia: WB Saunders; 1996.)



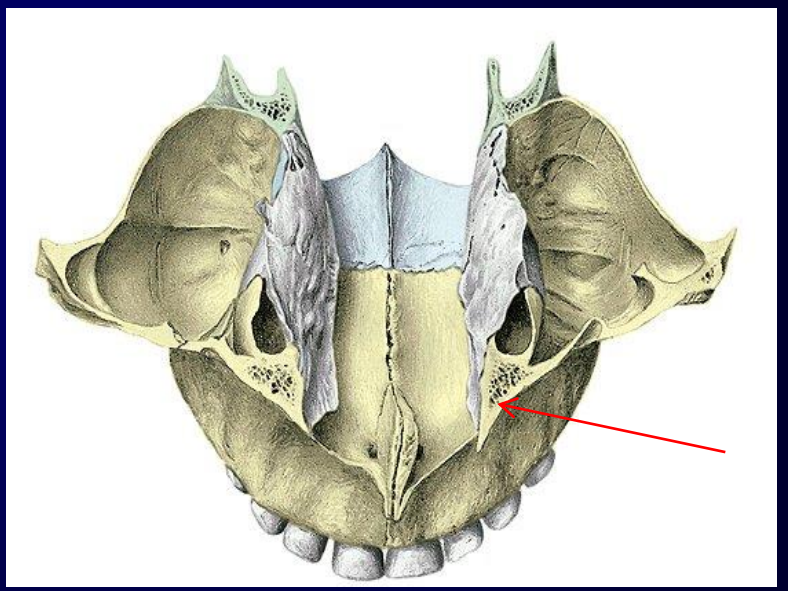
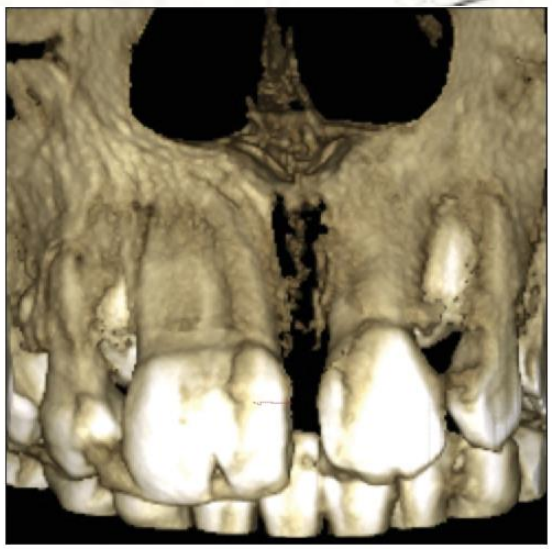


FIGURE 2-28 As the maxilla is carried downward and forward, its anterior surface tends to resorb. Resorption surfaces are shown here in dark yellow. Only a small area around the anterior nasal spine is an exception. (Redrawn from Enlow DH, Hans MG. Essentials of Facial Growth. Philadelphia: WB Saunders; 1996.)

Zpředu
Anterior view



: 4: Cone-beam computed tomography with three-dimen

Maxila + premaxila

Spina nasalis anterior

Foramen infraorbitale

sutura incisiva + sutura intermaxillaris
assist in anterolateral rotation of premaxilla - The phenomenon is described as the so-called ´opening bridge´.

Maxillary changes with age

Along axis crossing intraalveolar septum between deciduous lateral incisor and caninus

(„opening bridge“)

ventrocaudally

Sutural influence: frontomaxillaris, zygomaticomaxillaris, pterygopalatina

Sutural influence: incisiva et intermaxillaris

caudally

septum nasi

Influence on the surrounding structures

postnatally is seen also

sutura palatina mediana (7-19 year growth about 5 mm)

➢ At birth:

I. The **transverse** and **antero-posterior** diameters of the bone are **much greater** than the **vertical**.

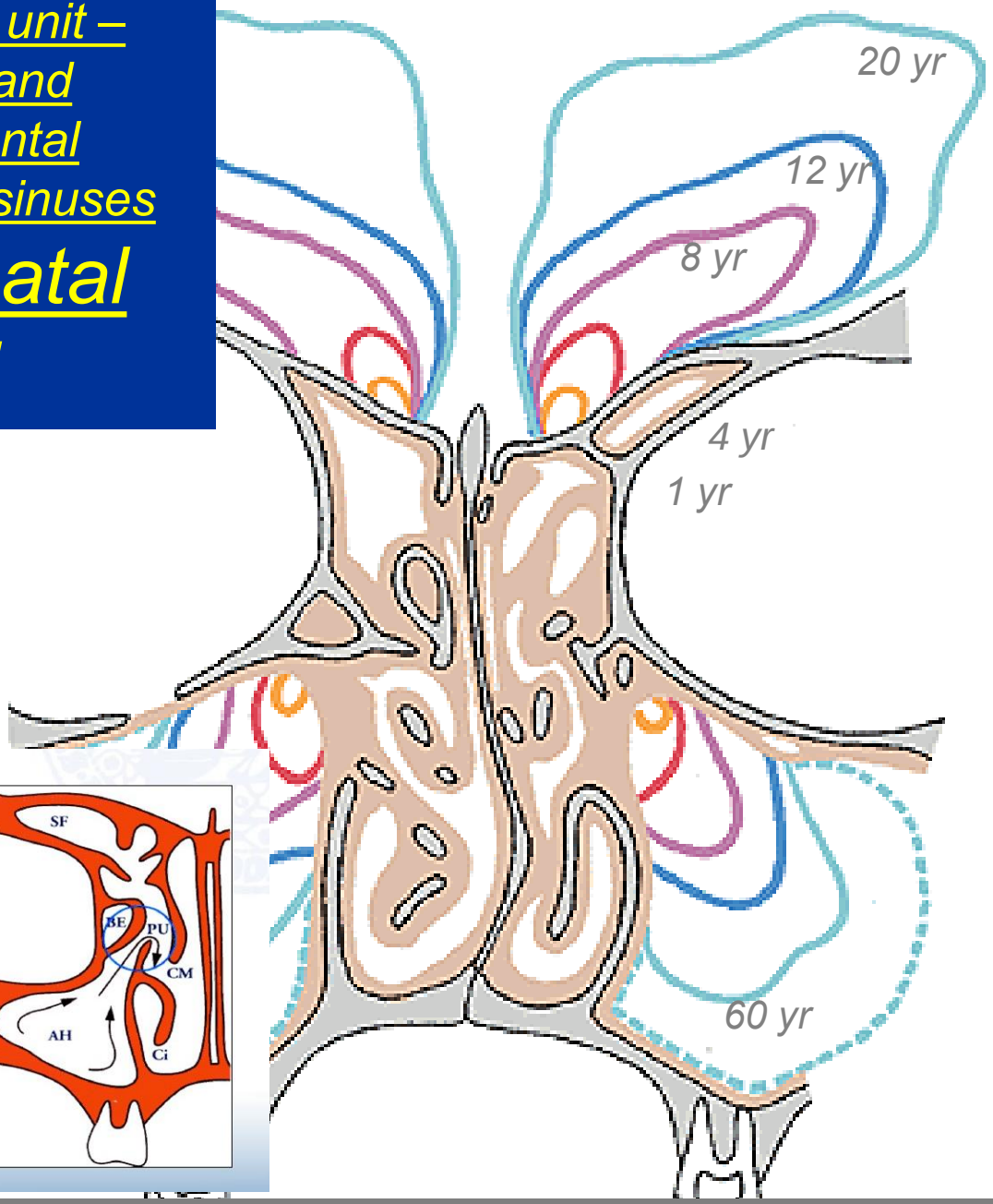
II. The **frontal process** is well-marked and the **body** of the bone consists of **little more than the alveolar process**.

III. The **teeth sockets** reaching almost to **the floor of the orbit**.

IV. The **maxillary sinus** presents the appearance of a **furrow** on the lateral wall of the nose

"Ostiomeatal unit – functional and developmental connection of sinuses

ostiomeatal unit"

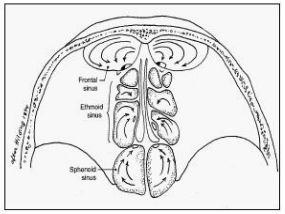


N. Highmore: Corporis humani disquisitio anatomica; in qua sanguinis circulationem in quavis corporis particula plurimis typis novis ac aenigmatum medicorum succincta dilucidatione ornatam prosecuutus est. Hagai-Comitis [The Hague], 1651.

Maxillaris

Antrum

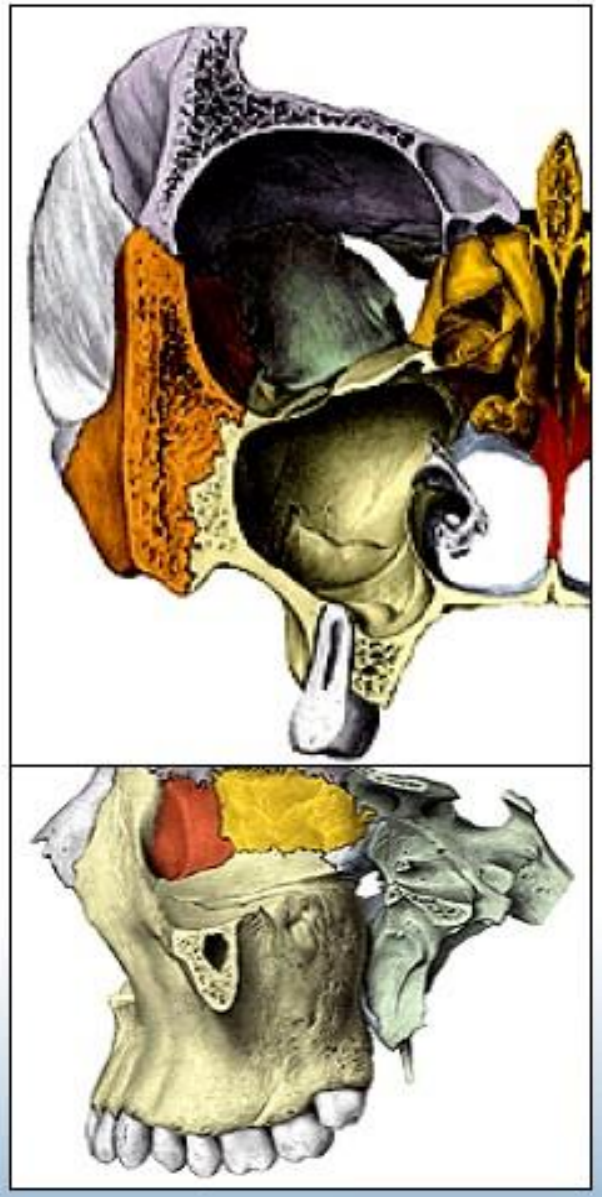
Highmori

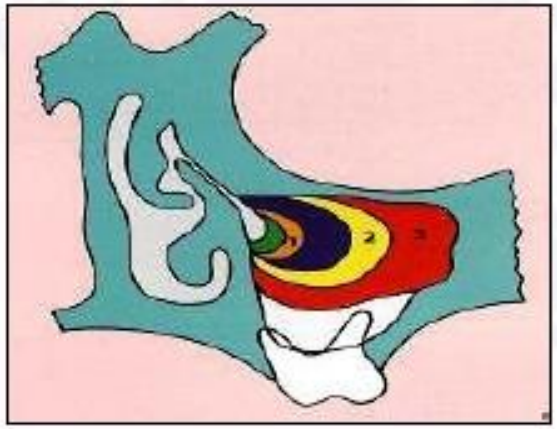


mukociliární clearance

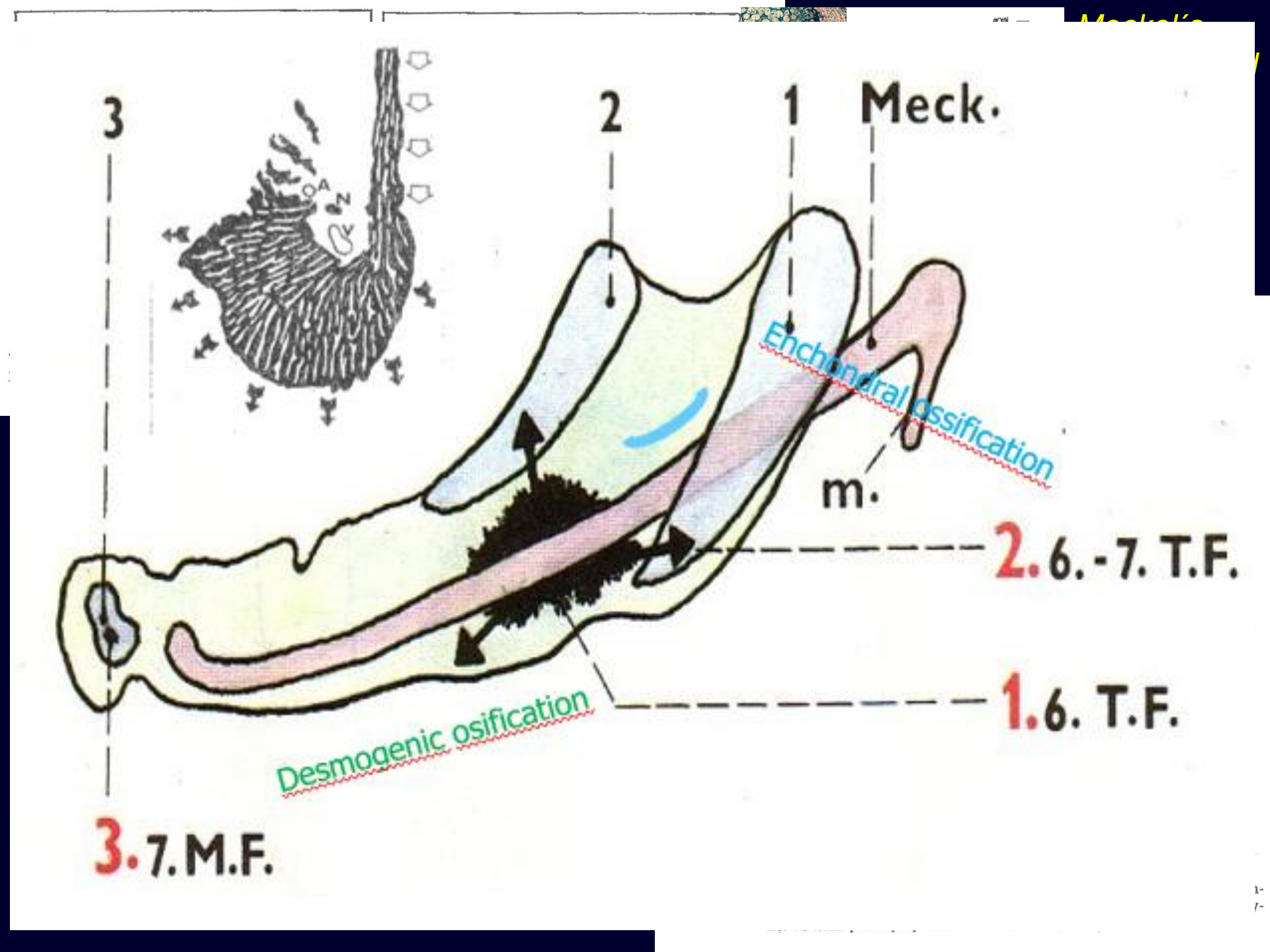
The sinus was well known to anatomists before Highmore. It had been illustrated by Leonardo da Vinci (1452-1519) and had been noticed by Giulio Casserio (1561-1616)

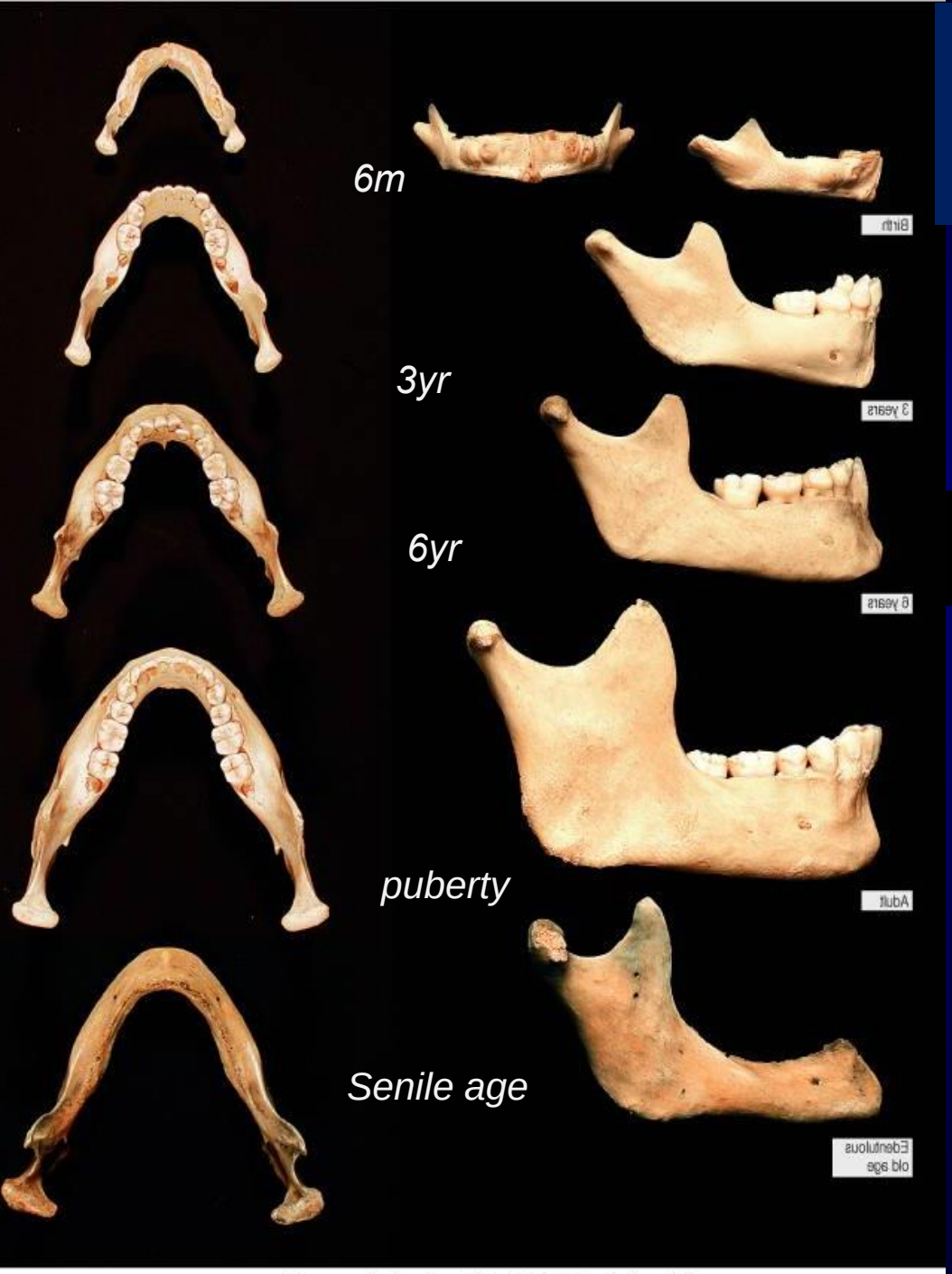
Sinus maxillaris





- antrum Highmori
- *birth*
  7x4x4 mm
- RTG
  4-5 *month*
- *biphasic growth*
  0-3 let & 7-12 let
- 18 let: 34x33x23 mm
- *topography*
  orbit - n. + vasa infraorbitalia
  pr. alveolaris – M1, M2, PM2, M3, C
  f. pterygopalatina & infratemporalis
  MNM – ostium + akces. ostia


3
2
1
Meck.
Enchondral ossification
m.
2. 6. - 7. T.F.
1. 6. T.F.
Desmogenic osification
3. 7. M.F.



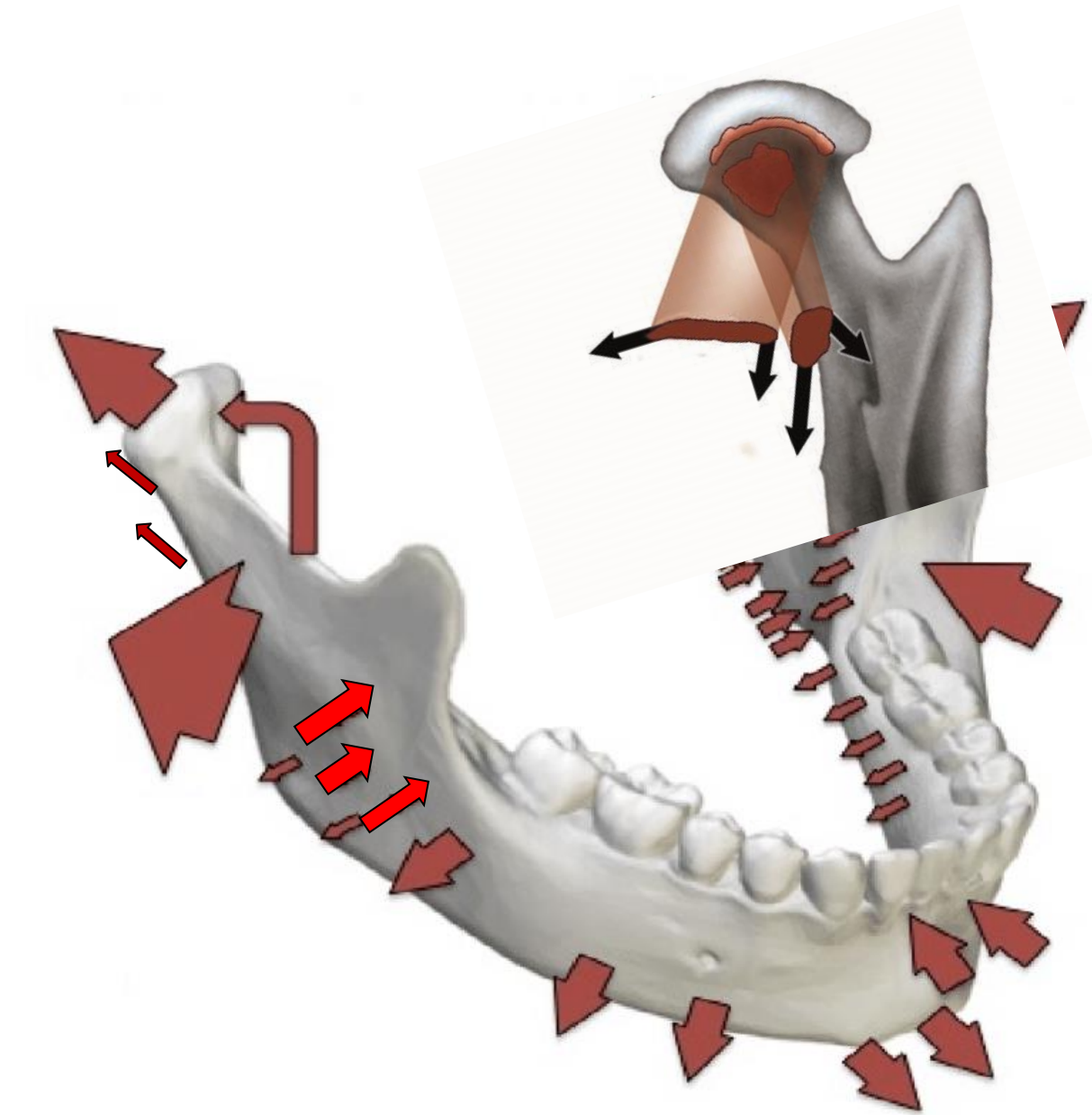
© Elsevier Ltd 2005. Standring: Gray's Anatomy 39e

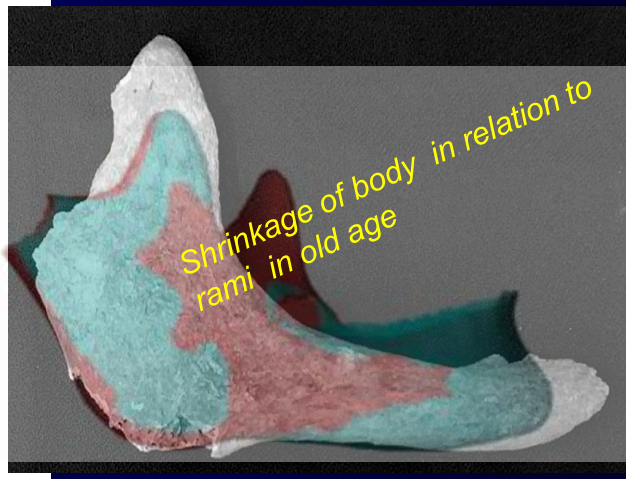
Jaw remodellation due to age *- BODY:* ***the front surface exhibits resorption (fossa mentalis); the back surface is appositional; apposition is only on the protuberantia mentalis***
- CHARACTER OF THE MODERN HUMAN

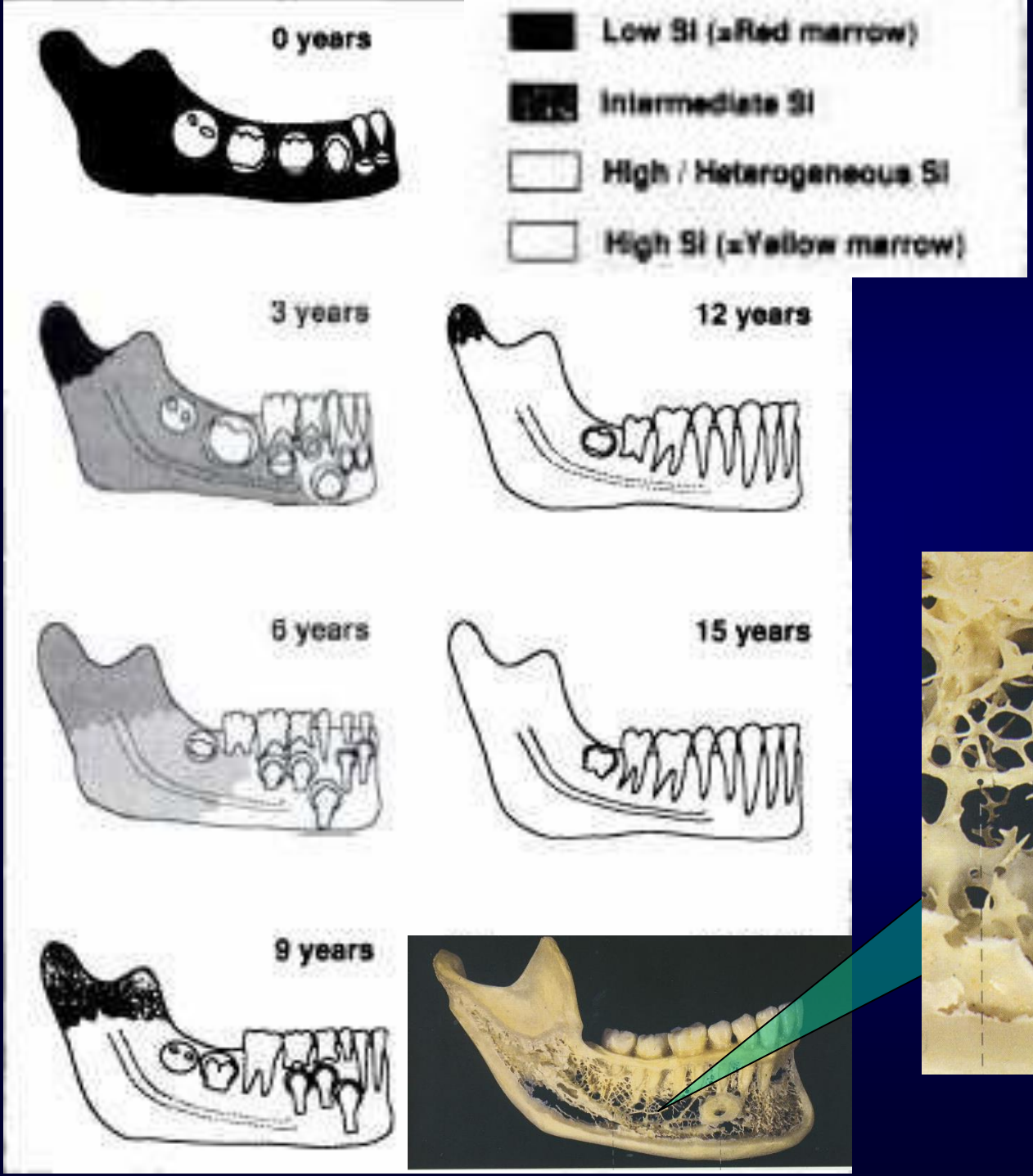
The ***Xiahe mandible*** *([ɕjâxɤ̌], sh'ya-khuh) Denisova Cave 160 000 year ago*

The width of the mandible in the body parts increases; it stretches forward with the growth of the protuberance the outer surfaces of the ramus mandibulae are resorbable, inner surfaces are appositional. At a lower level, the process is reversed.

Only in the ventral part of the body the resorption decreases until it is replaced by apposition - therefore the body is wider at the front than at the back.

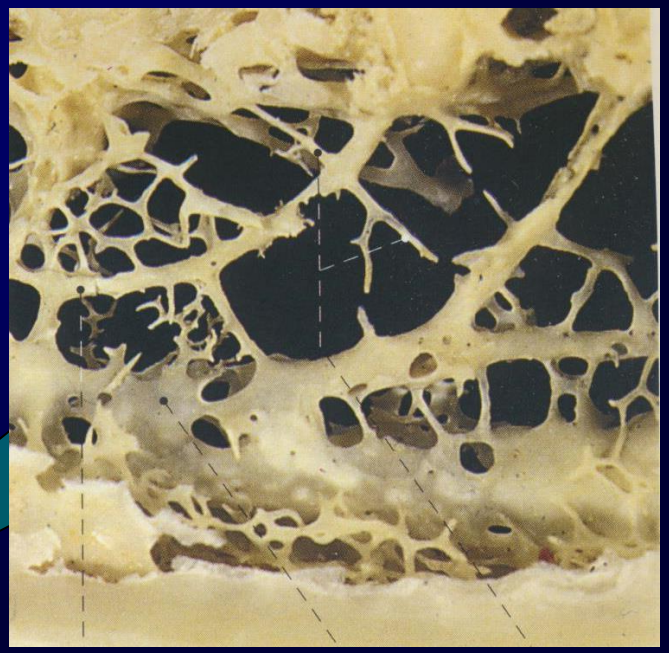



Shrinkage of body in relation to
rami in old age



Změny v konsistenci kostní dřeně

Changes of the density of bone marrow



Mandibular changes with age

growth follows spiral axis - mandibular logaritmic spiral growth pattern

Condyle growth

Remodelace chrupavky (direction of growth influences insertion of lateral pterygoid muscle)

Relocation of the ramus mandibulae

Vertical growth and formation of alveoli

Appositton material on dorsal margine of ramus mandibulae

Reposition of foramen mandibulae: *(from location at level of alveolus to level of occlusal plane crossing wisdom tooth* *3 – 15 yr*

symphysis menti is missing

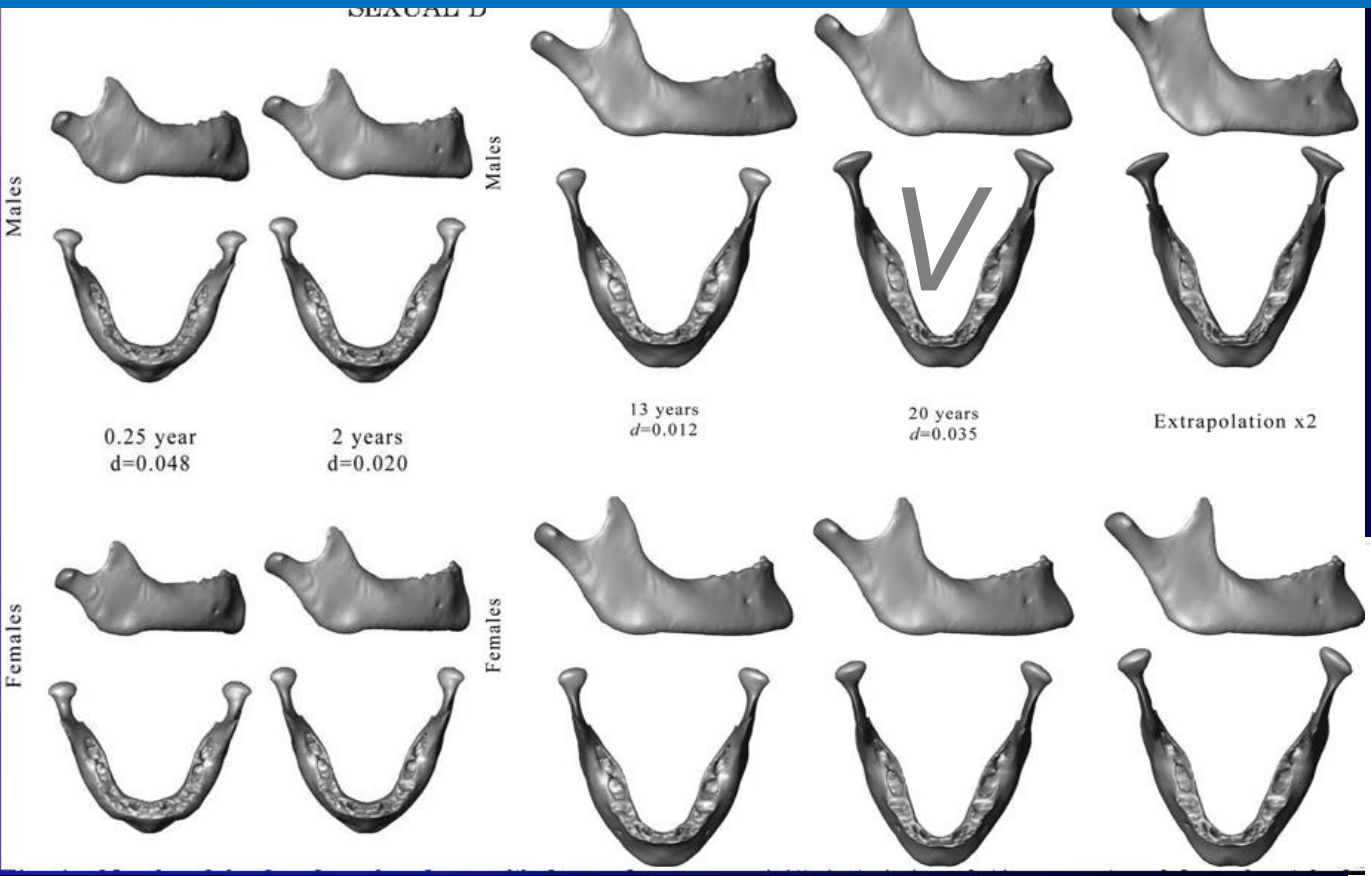
It is missing about 6 postnatal month (ventrally)

Elongation of the canalis mentalis

Interstitial growth

At birth, males have, on average, more advanced shapes than females. Gender differences then diminish rapidly.
This leads to an almost complete reduction in sexual dimorphism between the ages of 4 and 14.
From puberty to adulthood, the shape of a woman's mandible continues to change even after its size has stopped growing.
Dimorphism of dental maturation is observed in puberty.

Sexual dimorphism, especially in the ramus mandibulae, is not associated with tooth development. In puberty, the jaws enlarge significantly.



Linear shape regression from Age 13 to 20 years, viewed from the right lateral side and from a superior view. The thirdcolumn is the twofold extrapolation of the shape deformation between Age 13 and 20 years. The surfaces are regression estimates and are scaled to constant overall mandibular centroid size. The procrustes distance between male and female average shapes is given for each age stage.

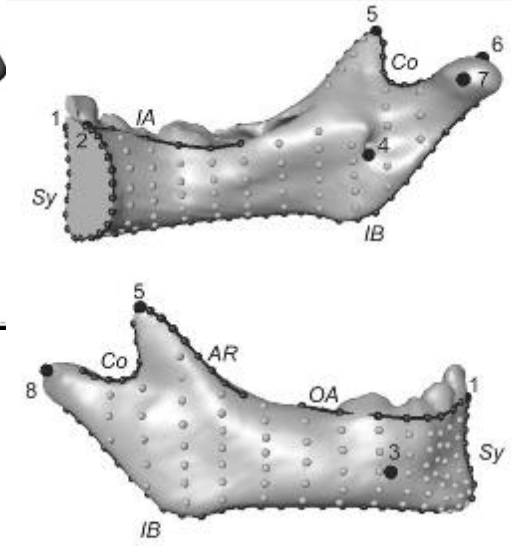
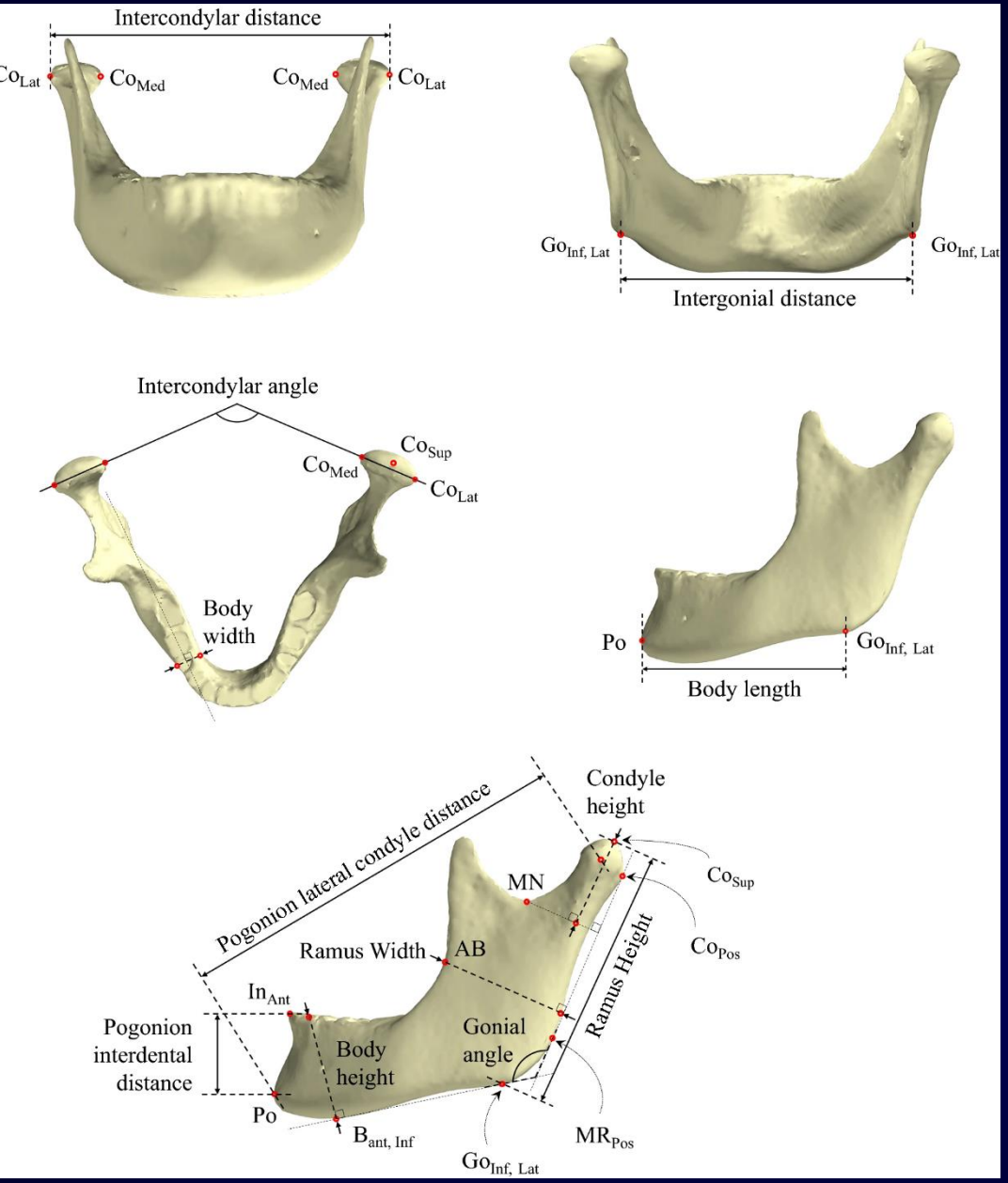


Fig. 1. Mandibular template (right hemi-mandible). Top: landmarks (large black dots) and curve semilandmarks (small black dots and lines). Middle and bottom: right hemi-mandible of a specimen aged about 1 year with landmarks, curve semilandmarks and surface semilandmarks (grey dots). Names of the landmarks and curve semilandmarks are listed in Table 2.

Tvar a velikost ženských a mužských dolních čelistí s vzrůstajícím věkem při pohledu z pravé boční strany a shora. Velikost povrchu je odhadnuta matematicky vzhledem k ´ těžišti´ dolní čelisti. Jsou ukázány tvarové rozdíly mezi mužskou a ženskou dolní čelistí ve stejném věku

M. Coquerelle,F. L. Bookstein,J.Braga,D. J. Halazonetis,G. W. Weber, and P.Mitteroecker: : Sexual Dimorphism of the Human Mandible and Its Association With Dental Development. AMERICAN JOURNAL OF PHYSICAL ANTHROPOLOGY 145:192–202 (2011)



Statistické obrysové počítačové modely SSMs
statistical shape models (SSMs)

Anatomical landmarks and morphometric measurements used in mandibular shape prediction. For symbol definitions and descriptions of morphological measurements

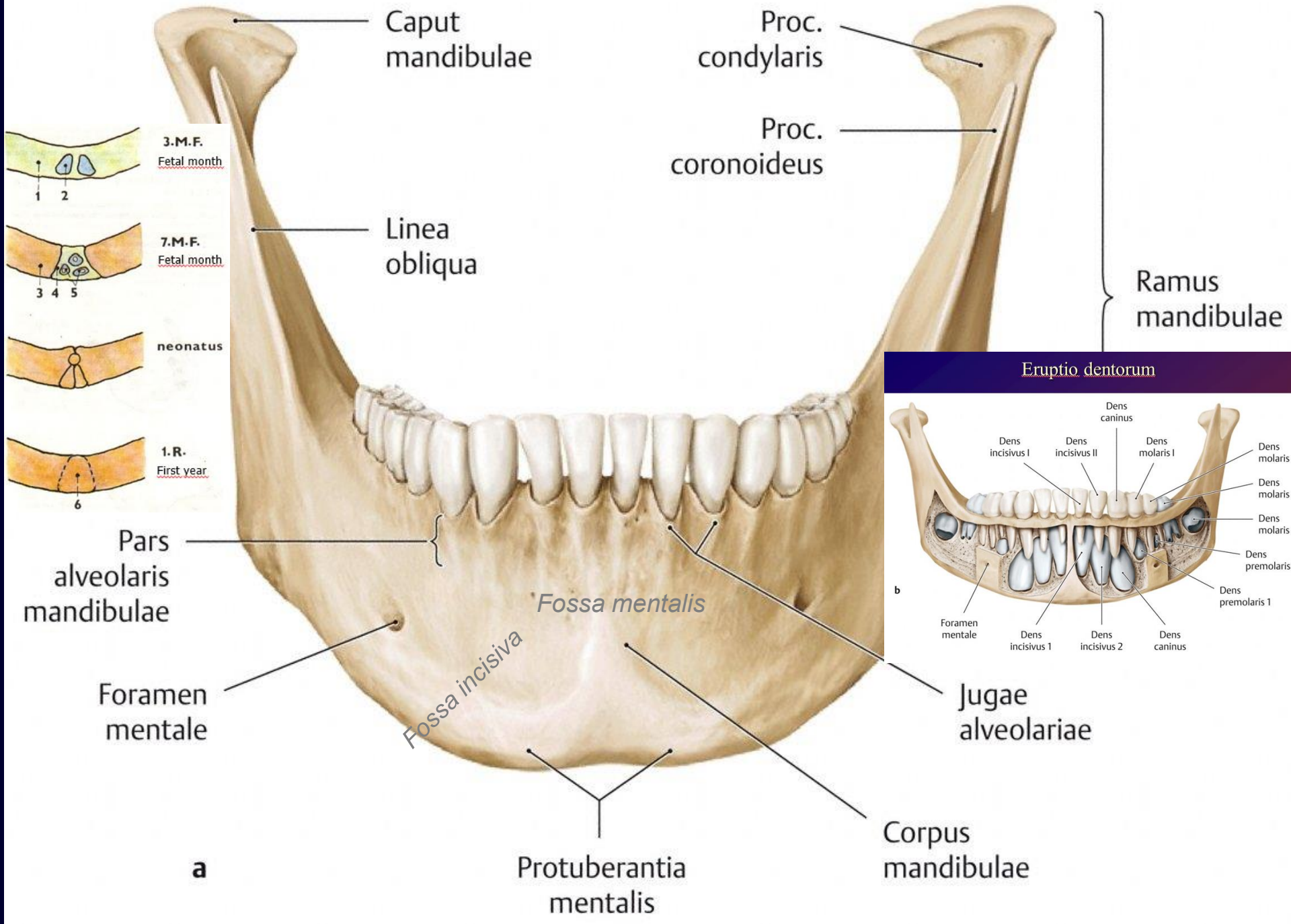
Seven morphometric measurements were found to make prediction of female and male mandibular shape optimally.

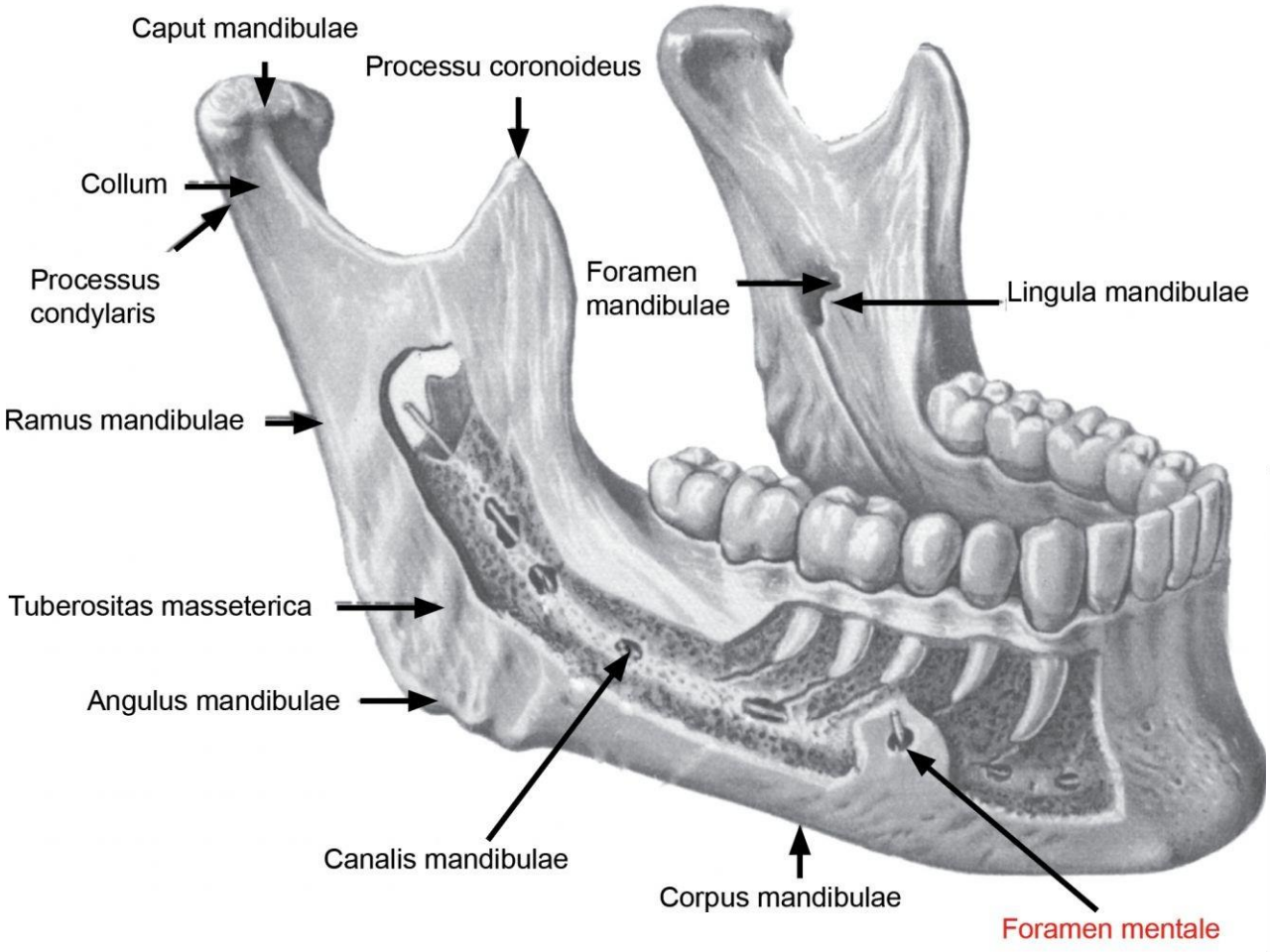
Sex-differentiating pure shape variations were observed to be most prominent in the **symphysis and posterior ramus regions of the mandible in comparizon with** size-normalised SSM.

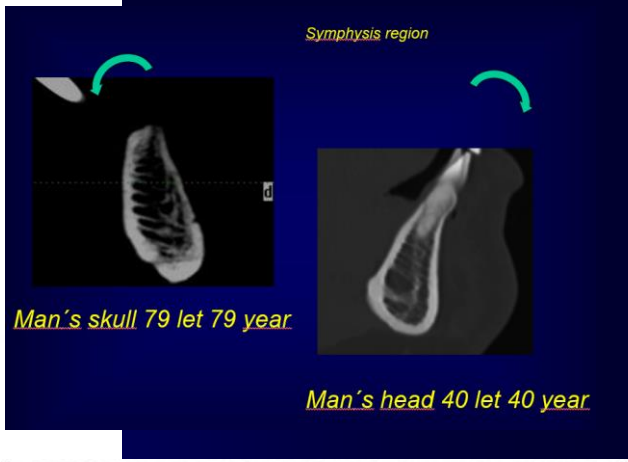
It be useful for implant development and pre-operative planning, particularly in the absence of bony structures following trauma or tumour resection.

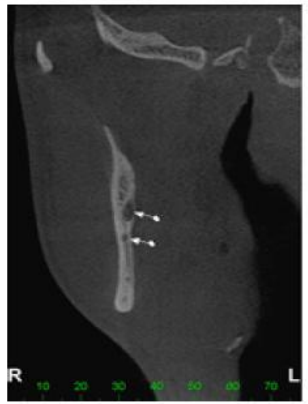
Ravin Vallabh, Ju Zhang,Justin Fernandez George Dimitroulis David C. Ackland
Biomechanics and Modeling in Mechanobiology ***volume 19****, pages 1187–1202 (2020)*

The morphology of the human mandible: A computational modelling study; *Biomechanics and Modeling in Mechanobiology* ***volume 19****, pages 1187–1202 (2020)*


Caput mandibulae
Proc. condylaris
Proc. coronoideus
Linea obliqua
Ramus mandibulae
3.M.F.
Fetal month
1 2
7.M.F.
Fetal month
3 4 5
neonatus
1.R.
First year
6
Pars alveolaris mandibulae
Fossa mentalis
Foramen mentale
Fossa incisiva
Jugae alveolariae
Corpus mandibulae
Protuberantia mentalis
a
Eruptio dentorum
Dens caninus
Dens incisivus I
Dens incisivus II
Dens molaris I
Dens molaris
Dens molaris
Dens molaris
Dens premolaris
Dens premolaris 1
b
Foramen mentale
Dens incisivus 1
Dens incisivus 2
Dens caninus

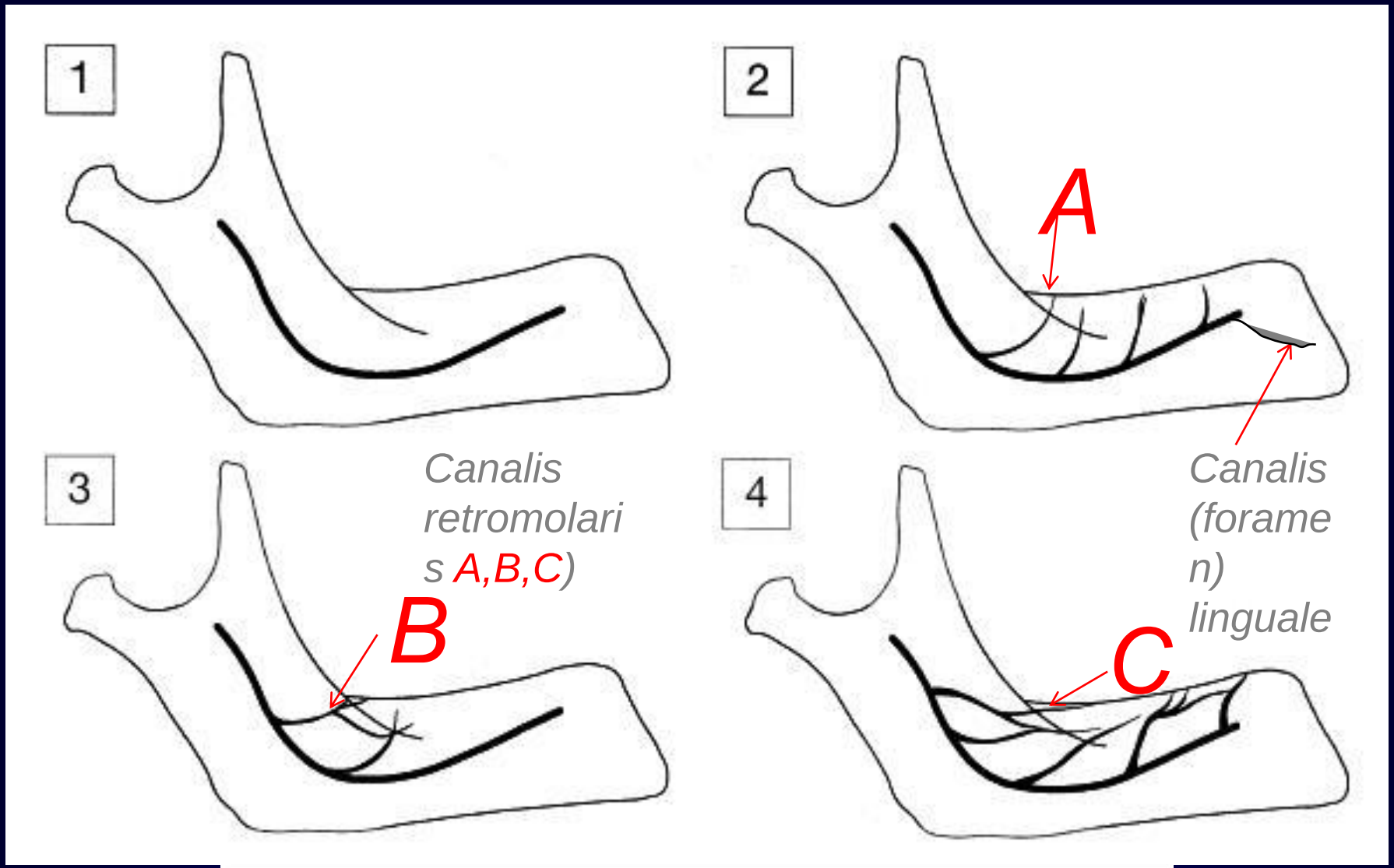


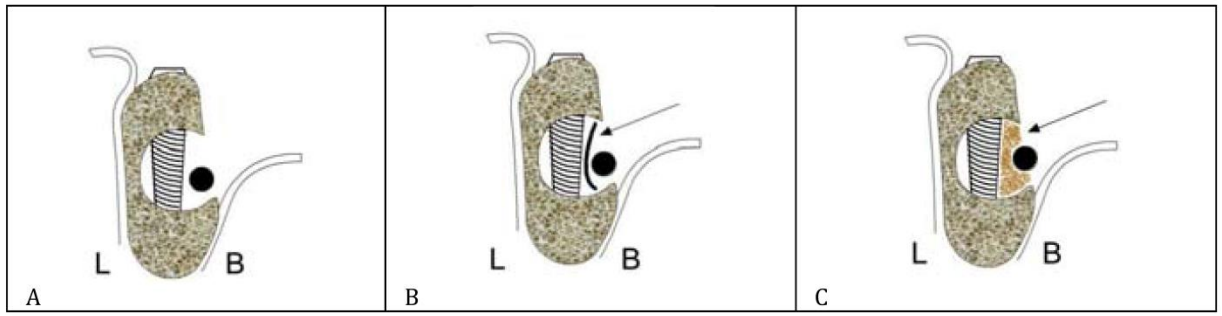




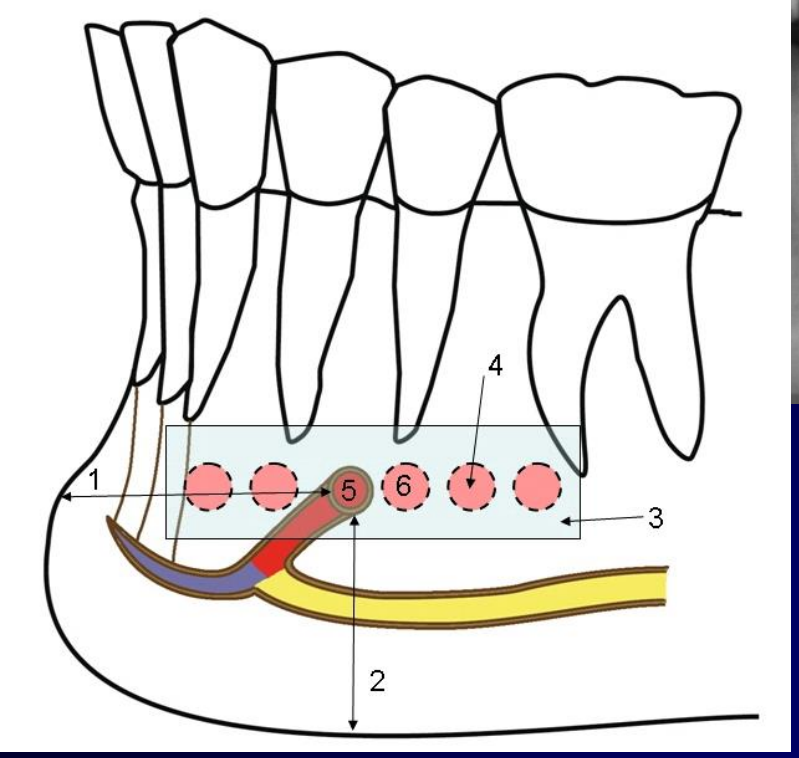
Grey 1918

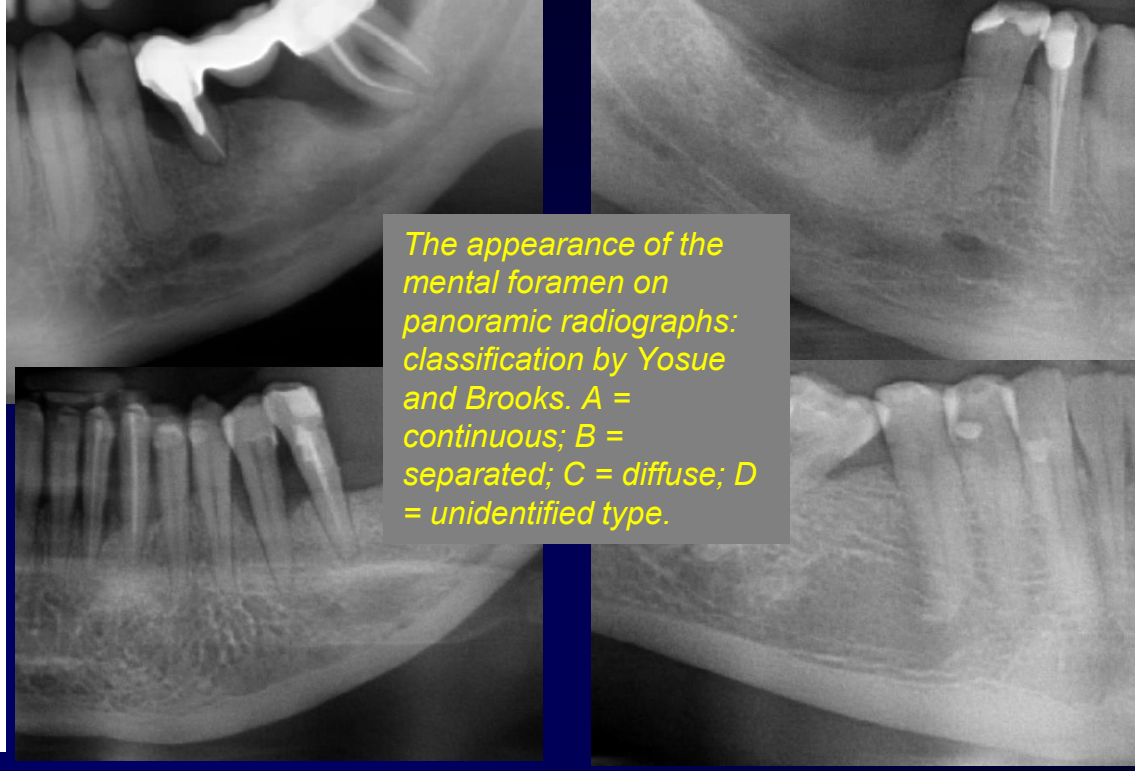
Gray's Anatomy: Descriptive and Surgical Theory; 1858





After Lang et al. 2002





The appearance of the mental foramen on panoramic radiographs: classification by Yosue and Brooks. A = continuous; B = separated; C = diffuse; D = unidentified type.

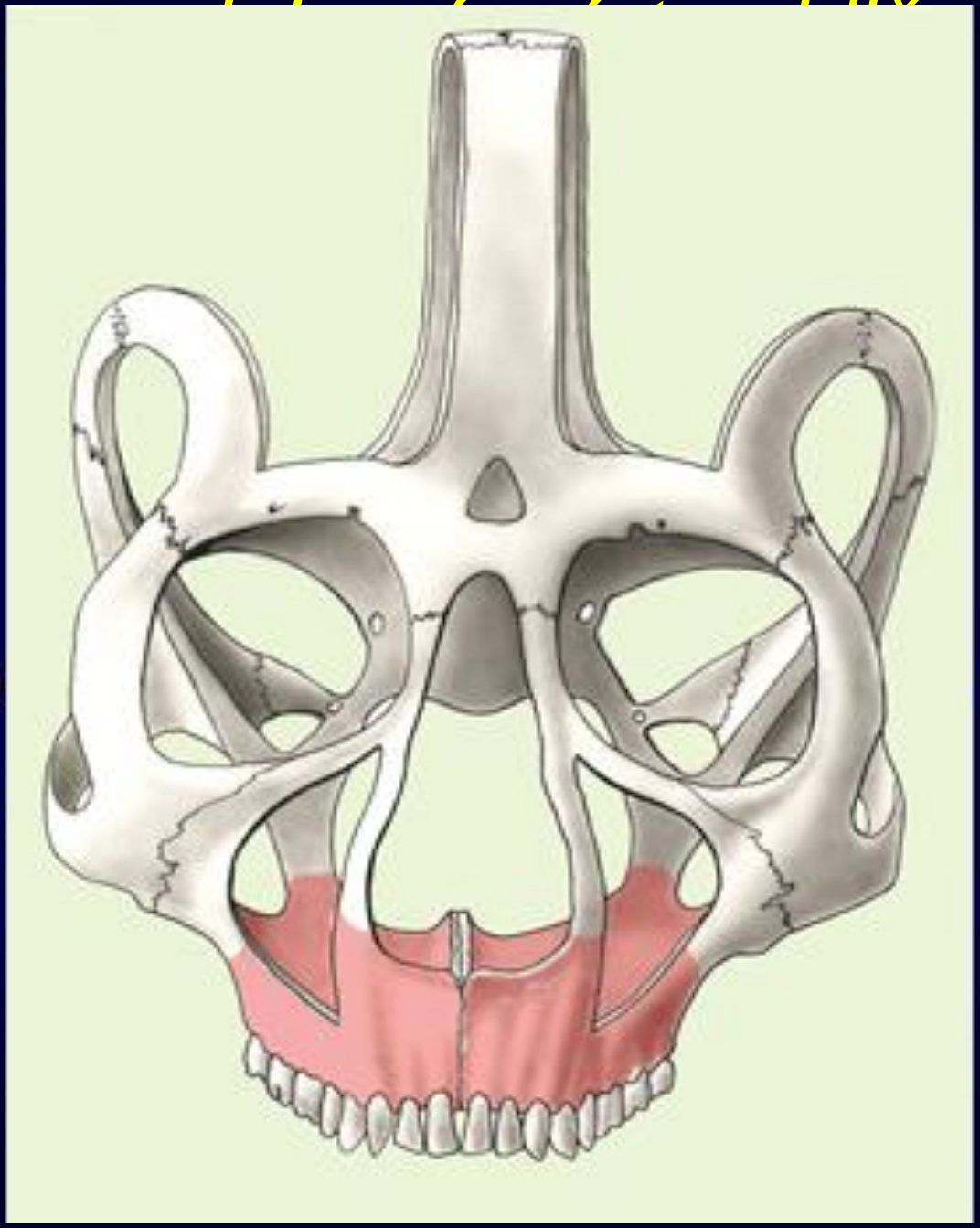
Anatomical variations of the mental foramen *(MF) position in the horizontal plane in relation to the roots of teeth.*

Colours: blue = MIC, red = mental canal (the anterior opening of the mandibular canal) yellow = mandibular canal.

1 = distance from MF to midline of the mandible (approximate distance 28 mm); 2 = distance from MF to the inferior border of the mandible (14 to 15 mm); 3 = possible MF location zone in the horizontal plane in relation to the roots of teeth; 4 = the shape of MF can be round or oval, the diameter is 1.68 to 3.5 mm; 5 = prevalence location of MF in the horizontal plane for Caucasian population; 6 = prevalence location of MF in the horizontal plane for Mongoloids and African people.

Patrová deska

Palate plate

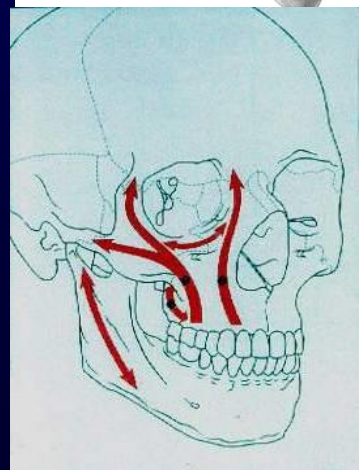


Podle Deffeze 1985

After Deffez 1985

Midface buttresses; tension and traction lines

- Three buttresses allow face to absorb force
  - Nasomaxillary (medial) buttress
  - Zymaticomaxillary (lateral) buttress
  - Pterygomaxillary (posterior) buttress



Transfer of chewing pressure to skull structures

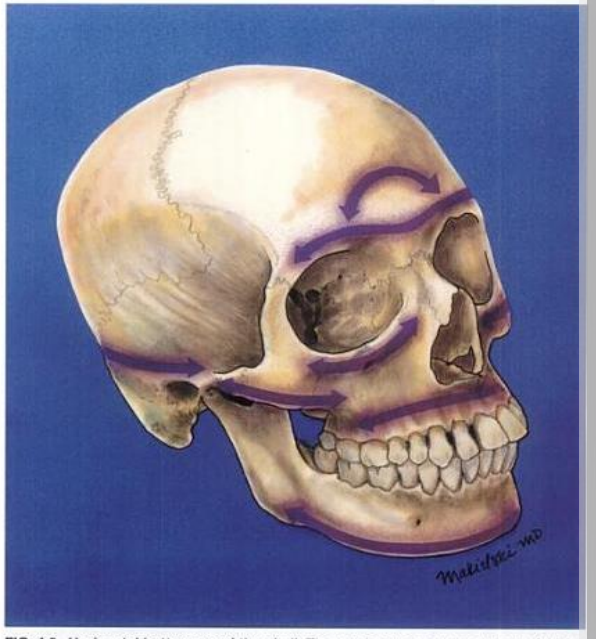


FIG. 4.8. **Horizontal buttresses of the skull.** The purple areas represent areas of thicker facial bone that are less likely to fracture than intervening areas.

Vertical and transverse pillars

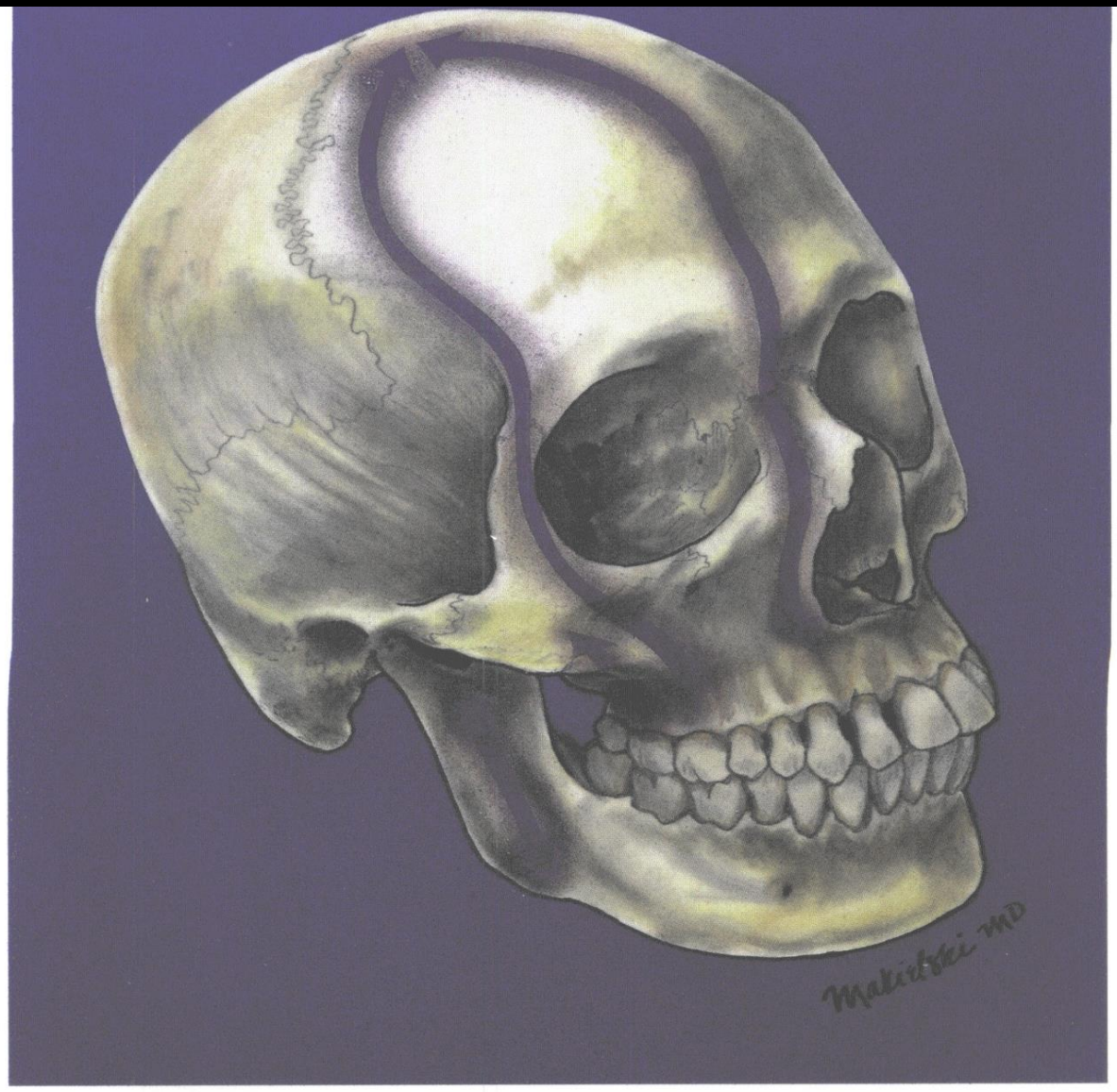
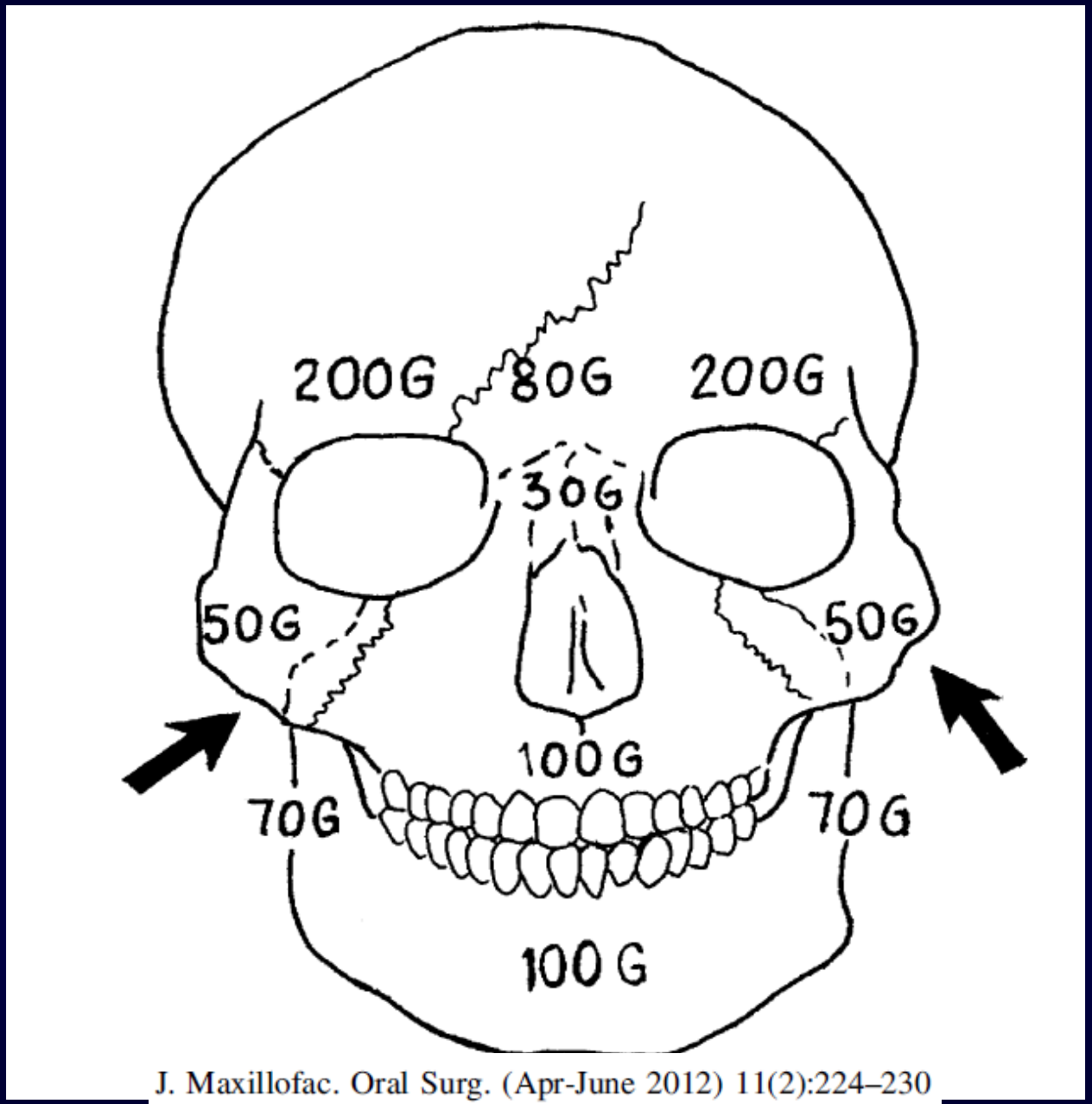


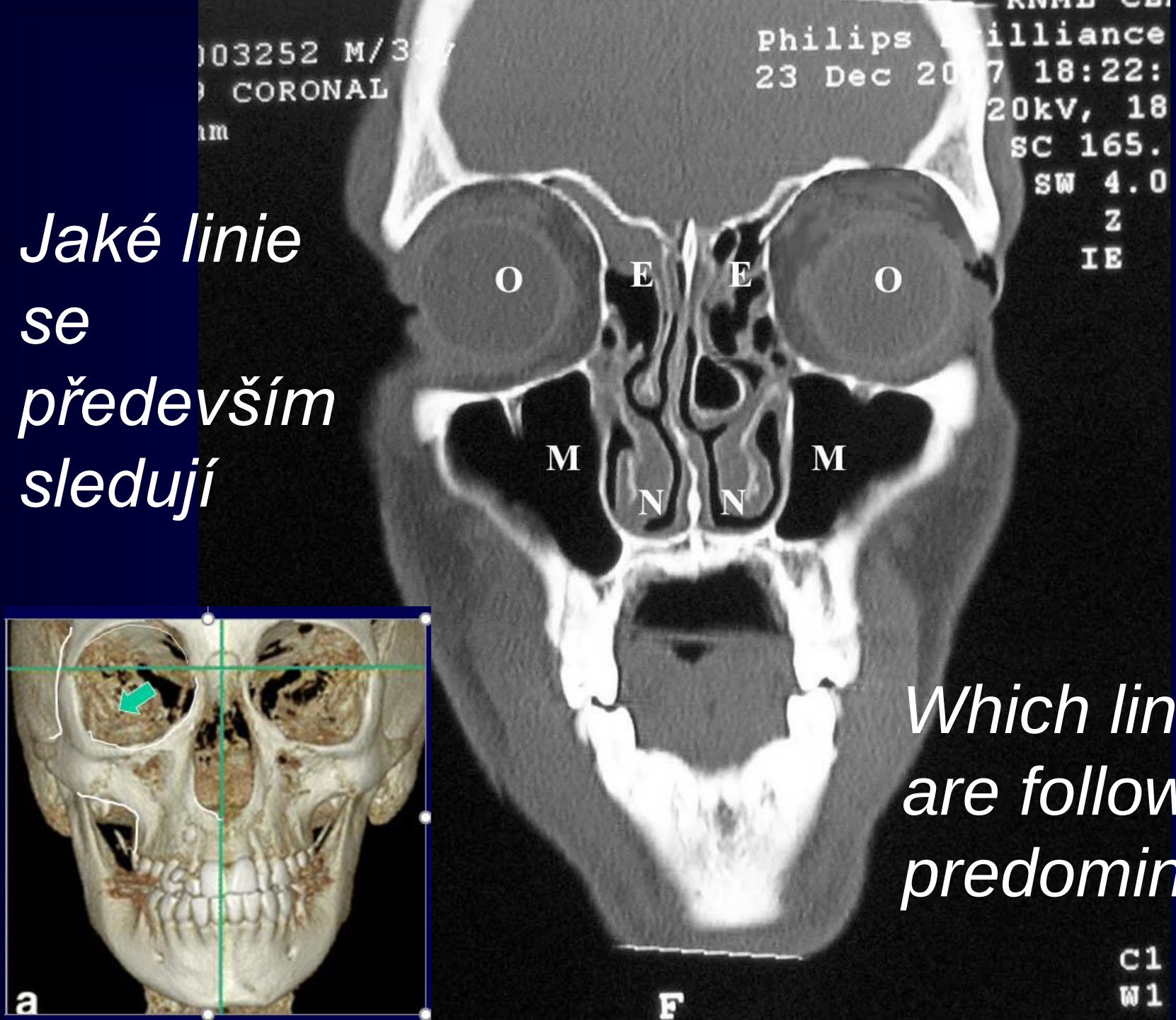
FIG. 3.9. Vertical buttresses of the skull. The purple areas represent areas of thicker facial bone that are less likely to fracture than intervening areas. Depending on the development of the sinuses, the buttress may follow the supraorbital rim and skirt the frontal sinus.

Classification of the facial bones into degree of resistance to impact



J. Maxillofac. Oral Surg. (Apr-June 2012) 11(2):224–230
DOI 10.1007/s12663-011-0289-7

Jaké linie se především sledují



Which lines are followed predominantly