

Intra-Oral and Peri-Stomal Changes Engendered by Evolution of Orthograde Posture and Bipedal Gait

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Abstract

This overview attempts to explore the much neglected changes taking place in the head and neck regions of the biped hominid. The changes, especially in the oral and peri-stomal areas have not received the attention they deserve. An attempt is made here to describe and discuss the anatomical adaptations brought about by the shift from a quadruped to biped posture and gait. Metrical and morphological alterations in the functional anatomy of the maxilla, mandible, dentition and the cranial base are focused on. Without these crucial adaptations erect posture and biped gait may well be compromised or rendered ineffective.

Keywords: Mandible; Impacted molar; Orthograde posture; Gait; Evolutionary biology; Physical anthropology; Sinuses

Introduction

Evolutionary biologists, kinesiologists and physical anthropologists have for long made the post cranial skeleton as core of their research. The metrical and morphological changes in bone and musculo-ligament size, shape and disposition that accompanied shift from a quadruped to biped gait are analysed and explained. Almost every pre-pelvic part of the biped skeleton reflects adaptive alterations to their anatomy as consequence of hind-limbs taking over the weight bearing and locomotor functions. Erect posture in the hominid has engendered multiple adaptive changes in musculo-skeletal and soft tissue elements. While the primary focus of evolutionary anthropological study has remained in the post cranial regions, much adaptive change in the head and neck regions brought about by orthograde posture and biped gait [1,2].

The review touches on the oral appurtenances as a proto-limb, then undergoing change and adaptation to the needs of biped evolution by reducing in dimensions, shifting weights, developing pneumatism, minimizing size and shape of teeth, altering cervical joint configurations and finally altering the entire biomechanical balance of the head [3-7].

Discussion

The mouth as a Proto-Limb Limb It has been observed that in some animals, using mouth/nose/tail as accrements that can aid or initiate movement: yet it would seem strange to learn that the ability use mouth parts are adjuncts to movement. The description of the atavistic orofacial reflex is example of how the mouth, involuntarily, plays a role. Years of observation over large populations have reinforced my surmise that a hitherto unnoticed facial reaction is a legacy of atavism. The higher the degree of digital dexterity involved in the performance of manual tasks, the more striking is the involuntary reaction of orofacial muscles to the level of concentration the task requires. Watch a volunteer thread a needle; the individual either purses his lips, or contorts his mouth, or licks his lips, or bites his tongue tip.

An orofacial-lingual response to manual work? As this is a very widespread and universally human response, it must have either a functional or atavistic basis, if not so. In quadrupeds, simians specially, the mouth or its component parts, the teeth, lips or tongue, are used as adjuncts to bimanual work. The use of oral appendages as adjunct aids in performance of manual tasks certainly makes, tearing, ripping, or carrying food or material. Is the human involuntary reaction of facial grimace, twitch, wetting, or clenching the jaw, a physiological atavistic

trait carried over into the higher mammal? How does the contraction of orbicularis oris or the action of genioglossus muscle influence the performance of task at 'hand'? [4].

The cervical vertebrae in the biped forms a stack of bones articulating with each other through facets placed both superiorly and inferiorly on their transverse processes. These joints are packed together with short ligaments that allow cervical muscles and beyond to produce flexion, extension and rotation. The vertical disposition of the neck bones leads to a number of disorders in function and shape of the individual vertebrae. Osteoarthritic changes in hip and knee and formation of extra 'accommodative' uncovertebral (Luschka's) joints [5] in the neck are often seen in older bipeds (Figure 1).

The skull, cranium, vertebral column, upper limb and sacrum show changes in the biped. The human skull is unique in that it bears a number of bones that are hollow within. These pockets called sinuses are predominantly positioned in and around the anterior half of the skull and are known as paranasal air sinuses (Figure 2). The maxillary, frontal (paired) the sphenoidal and ethmoidal (unpaired) sinuses lie within the maxillae, frontal, ethmoid and sphenoid bones. Much time

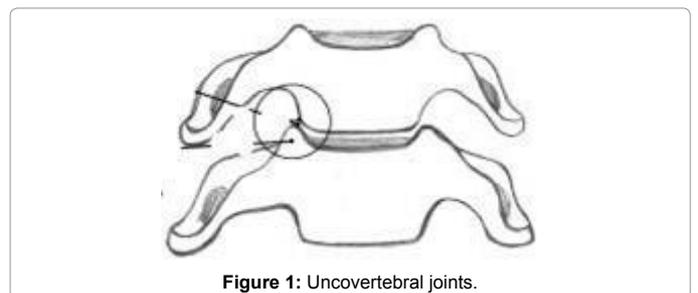


Figure 1: Uncovertebral joints.

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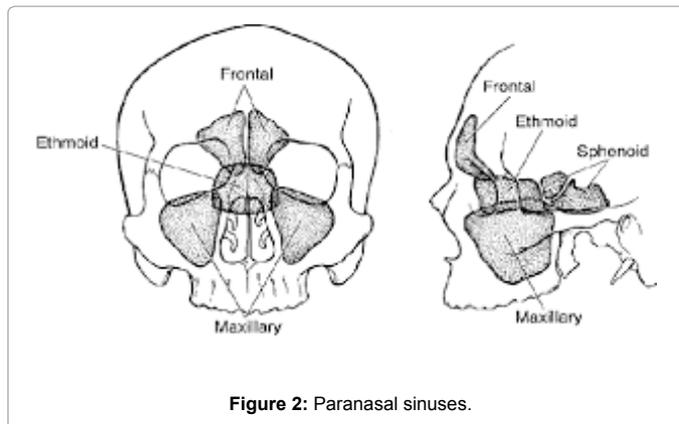


Figure 2: Paranasal sinuses.

and space has been taken up by physical anthropologists and human biologist in debating and discussing the reason for presence and roles played by air sinuses in the human skull. Among the many theories proposed, the few that are accepted as reasonably sound are:

- a. The sinuses lighten the skull weight.
- b. The sinuses warm inhaled air
- c. The sinuses provide resonance to human voice
- d. Provide protection
- e. Play a role in humidifying inhaled air

The skull is a heavy unit of bones supported and held up merely through two small articular facets on the atlas (1st cervical) vertebra. It is quite interesting to observe that such a massive weight contained in the by the skull, a weight made up by bones, tissues, muscle mass, glands, vessels, meninges and the brain, has just a pair of supports – the two atlanto-occipital joints.

The human head weighs around 3.5 to 4.5 kilograms. The entire cranial unit along with its suspended mandible bears down on the atlanto-occipital joints to be held up, extend, flex or rotate. As the supporting pillars formed by the cervical vertebrae are (as viewed from the norma lateralis) is positioned more towards the posterior third of the skull base, every part of the skull along with the mandible lies in front (anterior) to the weight supporting joints. Imagine the unit as simply osseous, without muscular, membranous (atlanto-occipetal) or ligamentous attachments – the entire head would tilt forwards (flex). The long arm of the lever lies anterior to the fulcrum (atlanto-occipital joint); the short arm extends posteriorly. Obviously there is an extra weight in the front of the fulcrum, forcing the skull of nod forward (flex) by itself *in situ*. To counter the mechanical skew, one needs to hinge (slide) the skull backwards to maintain it at even keel in a horizontal plane. The parity is restored only when muscles and ligaments counteract and overcome the skewed weight ratios. This is where one observes the multitude of muscle masses attached (splenius capitis, semispinalis capitis along with muscles in the suboccipetal area) to the squamous part of the external occipital crest, which itself provides mooring to the ligamentum nuchae, another major factor maintaining head leveling.

Note that all these muscles lie behind the atlanto-occipital joints – their contraction producing extension of neck. Yet another muscle, the sternocleidomastoid, attached above to the mastoid process and below to the clavicle and sternum, crosses the joint above downwards obliquely. Its contraction too extends the head. The trapezius, along with the

ligaments and stylohyoid, stylomandibular, sternohyoid and the strap muscles that attach to hyoid play accessory roles in the extension and maintenance of balance of the cranium/head.

Taking a new look at within the skull, the posterior cranial fossa in the biped is situated a step lower than the middle fossa, bringing its content the cerebellum, to lie lower than the temporal and occipital lobes of the cerebrum. In quadrupeds the cerebellum lies approximately at the same level (or slightly below) the cerebral hemispheres. The shift in position of the hindbrain from behind the forebrain to below it and the adjunct displacement of the posterior cranial fossa to a level lower than in the quadruped skull, reduces the forebrain to hindbrain angulation, enabling the head to be held vertically up the vertebral column without pressurizing, stressing or straining the spinal cord. The entire relocation of the osseous and nervous components in the posterior third of the head demonstrates that in needing to hold the head vertically up at erect posture and in bipedal gait, the shift in weight of the cerebellum to its completely new position, infero-posterior to both, the cerebrum and the atlanto-occipital joints, raises the weight of the short arm of the lever (fulcrum at the joint).

The key postural reflex or major site in the kinesthetic sense is located at the atlanto The entire relocation of the osseous and nervous components in the posterior third of the head demonstrates that in needing to hold the head vertically up at erect posture and in bipedal gait, the shift in weight of the cerebellum to its completely new position, infero-posterior to both, the cerebrum and the atlanto-occipital joints, raises the weight of the short arm of the lever (fulcrum at the joint).

Weight redistribution to offset forward is done by ‘emptying’ (hollowing) some bones that form the face and middle third of the skull. The maxillae, the frontals, the ethmoid and sphenoid are filled with air pockets – the paranasal air sinuses. Now that the evolutionary scheme of things re-morph the skull and relocate its contents to aid erect posture, bringing more ‘weight’ posterior to the atlanto-occipital joints, it also augments the mechanical skewing of advantage due to of lever systems functioning at the joints by reducing the weight in the long arm of the lever, the anterior third of the skull. To sum up, in going bipedal, the remote skeletal changes taking place are: The deepening and level lowering of the posterior cranial fossa. Shifting of the cerebellum from behind the posterior part cerebrum to below it. In effect, the cerebrum, cerebellum attempt to stack themselves one over another, instead of one behind another (as is in quadrupeds) to enable weight transmission along a vertical axis. Repositioning the occipital opening for the hind brain, the foramen magnum to its new antero-inferior location. Reshaping the slope of the basi-sphenoid (the clivus) to a steeper plane. Tethering, mooring and holding the posterior third of the skull through ligaments and muscles - ligamentum nuchae and sternocleidomastoid along with a number of localized short muscles and ligaments are operating in the suboccipital region. The taut atlanto-occipital membrane too functions as a tether. Reducing the weight in the anterior half/third of the head and skull by hollowing out bony matter from sphenoid, ethmoid, maxillae and frontals to form sinuses. The mandible is suspended from the base of the skull through its moor, the temporo-mandibular joint [6]. Its entire weight is borne by the skull in the biped. In the light of the discussion earlier on uneven distribution of weight of head along the horizontal axis with reference to the lever mechanism operating at atlanto-occipital joints, the mandible along with its dentition augments the load on the anterior arm of the lever. Despite compensatory mechanisms to counter the excess weight anteriorly (through repositioning of cerebellum and hindbrain and guy-wire like supports through occipital muscles), the anterior position of the skull too divests itself of some weight by emptying its sinuses of

osseous tissue. The mandible itself is light at birth (as related to head weight) increasing in dimension and weight as age advances. In a fully developed adult mandible a full complement of teeth adds to the total weight of the bone.

The question is can the bone itself try something different to shed weight as a part compensation to restoration of lopsided weight ratio anteriorly and along the horizontal axis passing through the fulcrum (atlanto-occipital joints)? In early man, just trying out a few strides of bipedal gait, the mandible was a massive chewing unit: with time and refinement in an overall reduction in mandibular body size and dentition in weight of the jaw evolved simultaneously. The alveolar ridge itself shortened in length crowding out space for growth of the third molars. The impaction of the growing molar is one of the more common afflictions seen by the dental surgeon.

Herein I may add that the mysterious (but uncommon) presence of the 'Stafne's cyst [7]. In the ramus of the mandible – considered by some to be an embryonic relic, could in some probability be a natural event in evolutionary biology to reduce the weight of the mandible itself (Figure 3). Similar too, is the fate the maxillary third molar: it too finds itself edged out by the reduction in space available on the alveolar margin. One of the theories is that the wisdom teeth are vestigial third molars that used to help human ancestors in grinding down plant tissue. While possibly true, the more rational inference could be that the molars were lost as price paid for by man for going erect and biped.

Add the weights of the four molar teeth to that of weight lost by absence of osseous matter from the sinuses to overall reduction in body size and weight of mandible and maxilla – a factor that costs dentition to pay a heavy price by way of frequency in impactions of the last molar (Figure 4) and you end up with a fairly large reduction in total weight in the anterior part of the head.



Figure 3: Mandibular bone cysts (Stafne).

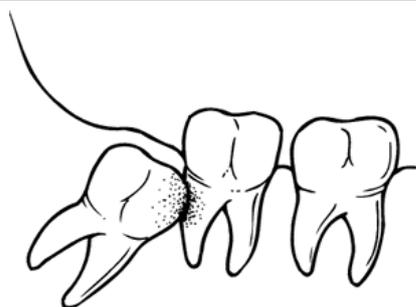


Figure 4: Impacted molar.

Moreover, besides infancy, in geriatrics too weakens the head and neck support props, ligaments and muscles and the head tends to sag or tilt forwards, perhaps, to offset the imbalance, the older the mandible becomes, the lighter it turns. In fact, age reduces weight and dimensions of the bone to an unimaginable extent.

Not only does its alveolar ridge erode and fail to moor teeth, all other parts of the bone, the body and ramus too shrink reducing the once heavy bone to a mere sliver. Reduction in size of teeth could also be a factor in minimizing skull weight: the australopithecine dentition was thickset and larger. In modern man the canines and molars have become smaller, much smaller when compared to that in early ancestor of man, the gigantopithecus [8].

Observing an infant on the move is perhaps the closest one can see the inherent 'quadruped' factors that are inbuilt. Firstly, a baby needs to be supported at its head end when being carried or lifted; the head wobbles when unsupported. Second, the mandible has no teeth. Third, sinuses are not seen as they are yet to develop. The first and second factors demonstrate that the head is too heavy for the infantile supports to hold it up, even without the additional weight of teeth or the lightening of weight through air sinuses.

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Conclusions

The remote and distal changes in morphological characteristics of muscle, ligament, fascia and bone of the head and neck in the gradual shift of posture and gait from the quadruped ape to the biped hominin makes for a fascinating area for study. The progressive and definite reduction in weight of the skull and mandible is not only discernible and metrical but also definitive and conclusive. There is much need for physical anthropologists and dental anatomists need to explore deeper into the distal and remote osteological changes, especially in the oral and peri-stomal areas.

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