Anthropology and orthodontics

Fred F. Crutcher, BS, DDS

Orthodontists are functioning anthropologists. We measure the bones of the face, skull, and teeth, and study the relationships of these structures. We should also be interested, then, in learning as much as possible about the origins of human beings and the evolutionary development of our anatomy.

Study of the other primates contributes to this field of knowledge. Primates are defined as mammals with thumbs and large toes that oppose the other digits. The ends of the digits are flattened and have nails rather than claws.[1,3] As we shall see, however, there are interesting exceptions.

Fossil evidence has uncovered a very old, very small, warm-blooded creature called megazostrodon. It had a sharp snout and pointed ears, nursed its young, and is the oldest known mammal. Geological dating places it on earth some 200 million years ago.[4] The brain of this mouse-sized creature was large in proportion to its weight and compared with the brains of other creatures then existing. It survived the Jurassic Age of the now-extinct terrestrial dinosaurs. It lived by its wits.

Charles Darwin was a close observer of nature. His theory of evolution grew from watching an undisturbed patch in his garden. He plotted the 2-by-3-foot area and carefully recorded every wild sprout of grass and weed. He followed the fate of each individual organism and continued his study for years.[5] He concluded it with three basic assumptions:

1. Each individual of a species is different from every other;
2. Each individual can reproduce in geometric proportion;
3. Because of a resulting overpopulation, only the most fit will survive.

Early primates

Tree shrews, the most primitive of primates, are an arboreal variation of the megazostrodon. When terrestrial living became too crowded or too hazardous, some individuals took to the trees. From them, tree shrews developed 50 to 60 million years ago, following the mass extinction of the dinosaurs.

The earliest extant remains of a hominid, the family of Homo sapiens (modern humans), are about 4 million years old. (That ancient being had ancestors whose remains have yet to be discovered.) These early hominids stood upright and although their cranial capacity was limited, it was relatively large for the overall size of this hominid. The orbits were surrounded by heavy bone, especially the glabella. The teeth were about the size of modern man's, but this creature stood only three or four feet tall.

Homo sapiens, maturing more slowly than other primates, retained many primitive features, which may be why the genus has been successful. Hands and teeth, for example, are quite primitive. Genera that become special-

Figure 1
Tree shrew

ized tend to become extinct when their environment changes. Special adaptations are beneficial only so long as the conditions to which the adaptation were made remain static. Climatic and geologic changes through millions of years reshaped environments, and organisms that failed to adapt became extinct.

This paper is an attempt to describe primate changes, particularly in vision, locomotion, and dentition, during the millions of years since the tiny tree shrew became arboreal, and to describe how present day man may be resisting some of these changes.

From shrews to humans

The tree shrew developed a shortened snout and an increased cranial capacity. Being nocturnal, its orbits are large and there is no bony separation from the muscles of mastication. It does not have stereoscopic vision. The shrew climbs vertically and scampers along the tops of branches. The large toe is flattened and has a nail, but the other digits have claws, which make the shrew's arboreal existence more secure. The basic mammalian (Eutherian) dental formula of 44 teeth[6] includes: 3 incisors (I), 1 canine (C), 4 premolars (P), and 3 molars (M), right and left, in both the upper and lower arches. The tree shrew fromulae are: upper I-2, C-1, P-3, M-3; and lower I-3, C-1, P-3, M-3. The teeth are generally more cone shaped than those of other primates. The basic building blocks for teeth are the cones, from which all teeth have evolved.

The next step up the primate ladder, lemur, includes numerous genera and subfamilies that vary in size from the attractive furry little mouse lemur to the cat-sized, ring-tailed lemur. Lemurs are good climbers, using their tails for balance. Their hind legs are well developed, allowing the lemur to leap along or between branches. Like the tree shrew, the lemur is almost entirely arboreal. Their digits have flattened ends on both hands and feet with nails instead of claws, except for the second toe, which is elongated and has a claw with which to scratch and groom (called the "toilet digit").

Lemur brains are more developed in vision, but less well developed in smell. The animal is nocturnal and has large orbits. As in the tree shrew, there is no bony separation between the orbit and the muscles of mastication. The snout of the lemur is less pointed than that of the shrew, and it projects beyond the lower jaw. The upper lip has a median cleft and is bound to the gums on either side. Its ears are large and mobile.

The dental formula for lemur, both upper and lower, is: I-2, C-1, P-3, M-3. The two central incisors are separated by a wide diastema, and like the laterals, are small and cone shaped. In some lemurs, the upper anteriors are entirely missing. The lower centrals and laterals form a specialized comb. They are elongated and procumbent, and are joined by the adjacent similarly formed canines. The lower first premolar has developed a canine form. The anterior comb is used for grooming, but has also been observed being used to scoop fresh gum and juice from trees.

A strange lemur genus is the aye-aye. It lives in cane brakes and bamboo forests where it bores into stalks for juices and grubs. Digits of the aye-aye have sharp curved claws on all but the great toe, which is flattened and has a broad nail. Its long specialized second toe is used for extracting grubs as well as for grooming.

The dentition of this creature is of special interest. The dental formula is: upper I-0, C-1, P-1, M-3; and lower I-0, C-1, P-0, M-3. The upper and lower canines are inclined labially and are in contact right with left. The teeth erupt throughout the lifetime of the individual, which maintains their length. Breaking into cane and bamboo, they perform much as the beak of a woodpecker. Upper canines of the aye-aye form in the maxilla rather than in the premaxilla, where the continuously erupting anteriors form in rodents.

The next species in primate evolution is the tarsier, which has a combination of primitive and advanced features. In past geologic times various genera of tarsiers were present in most parts of the world, and they became considerably diverse anatomically. There are some who believe that from these many genera evolved the branch leading to modern great apes and to man. Today only one genus remains: a small animal about the size of a two-week old kitten. Its habitat is confined to three islands in the Asian Pacific. This tarsier is arboreal and insectivorous. It is nocturnal with enormous eyes encased in bony sockets. The brain resembles that of a monkey, especially the part dealing with vision. The snout is shortened and the ears are large and mobile. The tarsier's hind legs are specialized for jumping, and the elongated tarsal bone accounts for the animal's name. The digits end with rounded pads that have nails.

Tarsier has the following dental formula: upper I-2, C-1, P-3, M-3; and lower I-1, C-1, P-3, M-3. All of the incisors and canines are coniform in shape as are the lower premolars and one of the uppers.

Next among these primates are the monkeys, with noticeable differences between old and new world monkeys. Most old world monkeys are no longer completely arboreal, instead combining arboreal life with excursions on the ground. Some, like the mandrill and baboon have become terrestrial. Monkeys have a quadrupedal gait, using all four extremities in locomotion. In the trees, they run and leap along the tops of branches. When hanging from limbs they have hands and/or feet on opposite sides of the limb. The monkey clavicle has become vestigial. Without it, the monkey cannot brachiate or hang with both hands on the same side of the limb and elbows extended laterally.

Monkey brains are more developed for vision and less for smell than the above-mentioned primates. They are diurnal and have stereoscopic vision, with their eyes on the front of the head rather than on the sides. Most monkeys have snouts that are quite blunt, with the exception of mandrills and baboons. The ears are rather small and close to the head. The dental formula for old world monkeys is: upper and lower, I-2, C-1, P-2, M-3. This is the same as that for great apes and hominids.

New world monkeys are almost completely arboreal, and much of their forest habitat covers swamps. Unlike any of the old world monkeys, most of the new world species have prehensile tails that have a bald sensitive area near the tip. The tail is used in locomotion, swinging, and even feeding. All of these monkeys use their tails for balance while ambulating or while sitting on all four limbs high in the trees.

The smallest of living monkeys is the marmoset. This new world creature has two rather than three molars in each quadrant. It also has curved claws on all digits except for the large toes, similar to the tree shrew and the aye-aye.

The dental formula for new world monkeys is: upper and lower I-2, C-1, P-3, M-3. Canines in both old world and new world monkeys are generally long and pointed and are used for fighting or are displayed as a threat.

There are four living types of anthropoid apes: gorilla, gibbon, orangutan, and chimpanzee. Fossil remains indicate many more existed at one time. These great apes have greater cranial capacity proportionate to body mass compared with the primates mentioned above. Being sexually dimorphic, males are larger than the females.

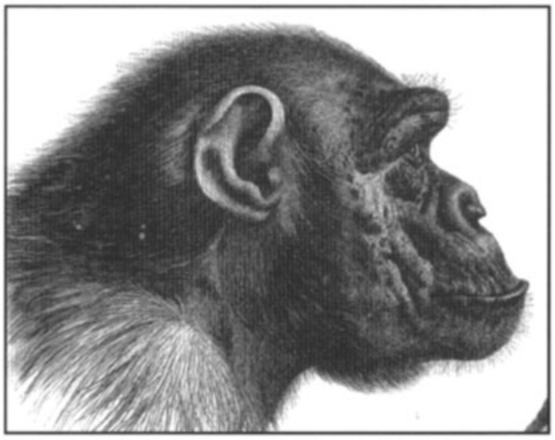
The gorilla is the largest of the four great apes. It is vegetarian except for occasional grubs, and this is reflected in its large grinding molars, especially the lowers. Gorillas have strong incisors with chisel-like edges. The central is larger than the lateral, which slopes gingivally on the distal; both have concave labial surfaces. There is a diastema between the laterals and ca-

Figure 2
Marmoset

nines in both arches. The maxillary premolars have definite buccal and lingual cusps while the mandibulars display a more subdued lingual cusp. As mentioned above, the dental formula is the same as in hominids, the other great apes, and old world monkeys.

Sexual dimorphism in the canines is well defined. Females have strong curved maxillary canines that extend well beyond the occlusal plane, while the mandibulars are conical in shape and extend only slightly above the plane. In males, the canines are like fangs; both upper and lower are robust, long, curved, and sharp, and are well adapted for defense and aggression. The gorilla is diurnal with stereoscopic vision. It has heavy bony ridges above the orbits. The ears are small and sit close to the head. Gorillas have become largely terrestrial, ambulating on all four limbs and using the backs of the knuckles and the soles of the feet. Like other great apes and hominids, gorillas have clavicles, which play an important role in brachiation. Gorillas brachiate, using the fingers as hooks over branches. The thumb has become small and rudimentary. Great apes and hominids have lost their tails, while tree shrews, lemurs, tarsiers, and monkeys all use theirs for balance in their arboreal running and leaping. Lacking clavicles, they do not brachiate. The toes of the gorilla are prehensile and all digits have flattened nails.

Figure 3
Chimpanzee



The gibbon is a world-class athlete. Its habitat is confined to southeast Asia and some offshore islands. It is almost completely arboreal. When descending to the ground, primarily for water, it ambulates in bipedal fashion, extending its arms high overhead for balance. It swings from branch to branch, using its long slender arms and sure grip. A web unites the index and middle fingers as far as the terminal joint. The gibbon doesn't need a balancing tail. Its locomotion is primarily brachiation and is not confined to walking and leaping; it's a real swinger. The lower limbs are diminished. Its habitat is now confined to the forests of southeast Asia. About 80% of its diet is fruit, augmented by leaves, flowers and buds, insects, birds' eggs, and nestlings.

Compared with other anthropoids, the gibbon's upper central incisors are broad and the laterals more pointed. Both are labially convex and lingually concave mesiodistally. The lower incisors are equal in size and shape and have sharp chisel edges. The upper canines are saber-like, being long and curved. The lower canines are large and conical, with the tips standing well above the occlusal plane. In occlusion, this tooth occupies a definite diastema between the upper lateral incisor and canine. The premolars are definitely bicuspid, with the lingual cusp smaller than the buccal. The lower first premolar is narrow mesially and widens to a definite buccal cusp distally, which slopes down to the curved cervical ridge that supports a small lingual cingulum. The second lower premolar is bicuspid, but the cusps are mesial and distal rather than buccal and lingual. In both upper and lower arches, the second molar is larger than the first and third.

The orangutan is arboreal and, like the gibbon, its locomotion is based primarily on brachiation. Its legs are shortened and its arms lengthened. The skull and face are elongated and surrounded by a heavy fringe of fur. The dentition is similar to that of gorillas except that the jaws are narrower. The canines are sexually dimorphic, again as with the gorilla. Where the gorilla's second molar tends to be larger than the first, the orangutan's are of equal size. Its habitat is now limited to a small region of marsh forests in Borneo and Sumatra. At one time it inhabited much of Asia, including China. The orangutan is seclusive and few are left, having been hunted by natives for food and by animal trappers for zoos.

Chimpanzees are both arboreal and terrestrial, spending about one third of their time on the ground. Although primarily vegetarian, they eat a variety of termites, grubs, and occasionally small animals that they kill. They select and modify twigs, which they use to extract termites from their mounds. The termites attach to the intrusive twigs and the chimpanzees lick them off. Besides these modified termite twigs, chimpanzees also throw stones and use stripped branches as striking weapons. Hominids are not the only toolmakers.

The chimpanzee's legs are not as proportionately diminished as those of the gibbon or orangutan, but their arms are long and strong. They can ambulate on their feet, but the anatomy of the femur and pelvis creates a swaggering gait. The backs of the knuckles and the soles of the feet are used. The chimpanzee is a good climber and brachiates. As with other great apes, the chimpanzee exhibits sexual dimorphism. The canines of males are heavier, longer, and more curved. Chimpanzee dentition is much the same as the orangutan's except that the dental arch is a little wider. Comparing chromosomes of the great apes with those of Homo sapiens, the chimpanzee is the closest match.

The change from arboreal to terrestrial life in Homo sapiens could not have occurred without changes in anatomy. The most reasonable explanation for these adaptations is changes in climate. Tropical forests gave way to forested areas interspersed with brush and grass. Savanna lands eventually predominated where forests had prevailed. Some forest areas became isolated and gradually diminished to the point of extinction. Arboreal primates became terrestrial or they perished. Where forests survived, arboreal primates, like those discussed above, survived.

Being grounded, the ability to rise up and see surrounding vegetation became an advantage. As Charles Darwin observed, no individuals are the same. Those best able to stand tall could see danger and food first. Upright locomotion freed the hands for balancing and carrying weapons, food, and offspring. Those individuals with legs closer together could walk or run with the feet closer to a straight line, eliminating the inefficient swagger of the great apes. New foods were required, as leaves, nuts, and fruits were no longer available. The hominid became an omnivore.

As structural changes occurred in the skeleton, the skull also adapted. The forward stance of an arboreal existence required strong muscles on the back of the neck and shoulders, which attached to three nuchal ridges on the top and back of the skull. With the weight of the head now resting on the spinal column, the foramen magnum has shifted from the posterior to the inferior of the skull. The strong nuchal muscles reduced and their articulating surfaces, the nuchal ridges, migrated down the back of the head.

The coarse diet of roots, leaves, seeds, and fruits required heavy muscles of mastication. Fossil remains show that early predecessors of Homo sapiens, or an extinct offshoot relative, had a crest of bone along the top of the skull to which these strong muscles were attached. Early hominids had robust zygomatic arches and glabellum.

Hominid fossil remains indicate upright posture existed before cranial capacity increased. The strong nuchal and masticating muscles formed a restraining muscular cap. Their retreat from the top and sides of the skull made expansion possible, allowing increased cranial capacity and development of the forebrain.

Homo sapiens are diurnal, have stereoscopic vision, and have greater cranial capacity than other primates and most other mammals. They are omnivorous and sexually dimorphic. They can brachiate and, having upright posture, can walk, run, and jump.

Upright posture exposed the jugular notch, that vulnerable spot above the sternum and between the clavicles. The forward stance of the other primates hid this vital weak spot, and when necessary, both males and females used ferocious upper canines to defend it. Losing those advantages, hominids developed a chinbutton, pogonion, which nicely defends the jugular notch when the head is ducked. Male Homo sapiens have larger chinbuttons than females. Males are the hunters and protectors and a larger chinbutton provides greater skin area on which a beard can grow, adding protection for the jugular notch.

Man and elephant are the only mammals with chinbuttons. The elephant has a very long and mobile lower lip, which aids in guiding the enormous amount of coarse food ingested daily. The chinbutton provides necessary muscle attachment for the lip.

The hominid chinbutton provides lower muscle attachment to orbicularis oris, the ring of musculature that restrains protrusion. Study of those selected for having untreated excellent occlusions finds that for each millimeter of chinbutton, there is a 4 mm reduction of the distance from the labial of the maxillary incisor to the facial plane.[2] Those who perform cosmetic chinbutton implants should keep in mind the disruption of this muscular resistance to anterior dental protrusion.

The lower extremities and pelvis of hominids adapted to upright posture, yet this was accomplished without a balancing tail: arms and hands suffice. Arboreal living occupied the hands, clinging to branches. The feet adapted to bipedal walking and running, but in doing so, lost much of their former prehensile ability. Some of us, however, carry with us Morton's toes, a second toe that is as long as the great toe. Is this in remembrance of that toilet digit of the lemur?

Conclusions

The canine, C-1, is the one constant number in all the dental formulae of the various primates. Even in the strange aye-aye, canines replaced the incisors. Is it possible that the forward mesial growth of the canines in the aye-aye is related to the palatal impacted canine presented by some orthodontic patients? Tarsiers have coniform incisors. Are they related to the pegged lateral incisors we see in some patients today? Are the occasional 90-degree-rotated premolars somehow related to the gibbon's lower second premolar, which is also rotated?

The left and right posterior teeth of old world monkeys and anthropoid apes are parallel, but hominid arches diverge distally and the canines do not protrude beyond the occlusal plane. This combination allows for greater lateral excursion and more efficient mastication. The posterior widening of the mandible occurred as the temporal bones widened with increasing cranial capacity. The maintenance of efficient occlusion and mastication would promote a corresponding change in the maxillary arch. In some of us, however the upper arch presents parallel rows of posterior teeth. We call it bilateral crossbite. Is this a regression to former maxillary morphology?

Diastemas occur in the very space two incisors occupy in the basic mammalian dental formula, I-3. This is also a site where supernumerary teeth, often coniform, are located. Supernumeraries are also often located in the premolar sites where tree shrew, lemur, tarsier and new world monkey have three premolars. Are these also remembrances? What about the split upper lip of the lemur? Is it an ancient precursor to hare lip? Are missing third molars somehow connected to the little marmoset? Premolars are two fused cones modified and molars present clusters. Is it not likely that the same phenomenon is at work forming occasional fused teeth? The man in the ice, discovered in Italy's Southern Tyrolean Alps, was from the late Neolithic age, 5200 years ago. He had a wide diastema between his maxillary central incisors and missing third molars.[7]

Charles Darwin's acute observation about individual variation evidences itself when considering all the above common anomalies. These variations are the experimental laboratory of evolution. Those mentioned above seem regressions, but perhaps they are progressions. They pertain to only a small portion of the interweaving systems of which we are composed. Not only anatomic, but physiologic, biochemical, and psychological differences probably carry within them a share of inherent and regressive aberrations. They are our connection not only to other primates and mammals, past, present, and future, but to all living things.

Author's note

The author has referred to incisors, premolars, and molars in this manuscript in terms understandable to dentists. Odontologists refer to central incisors as seconds and laterals as thirds. In monkeys, anthropoid apes, and Homo sapiens, the first incisor, both upper and lower, has been eliminated. The first and second premolars have also been eliminated, with the exception of the new world monkey in which only the first is missing. Reference to third incisors and third and fourth premolars would be confusing.

Author Address

Fred F. Crutcher, BS, DDS
10 Albo Ct.
Orinda, CA 94563-3901

F.F. Crutcher is a retired orthodontist and an armchair anthropologist. He presented this paper to the Angle Society of Northern California, September, 1996.

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