The Problem with the "Form Versus Function" Dichotomy

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Interest apparently remains high within the IAOM regarding the controversy and claims about whether form determines or follows function, or vice versa. Comments on some websites about muscle winning the fictitious war over bone, and claims about the envisoned tug of war for dominace between function and form, or muscles and bone continue. The purpose of this instructional memo is to clarify this controversy by revisiting where the controversy likely began - with the publication and discussion of "Wolff's law of bone". In the late 1800s, Wolff, a German physiologist, observed that the internal architecture of bones reflects the stress patterns on them. Bone trabeculae in the end of long bones (epiphyses) are arranged to follow these stress lines, indicating a relationship with surrounding muscles and supporting structures. This is well exampled in the head of the femur, but is also found in the head of the mandibular condyle where stress lines are arranged in a similar fashion to the femur, indicating a similar pattern of resistance to stress.

Wolff's early observatons of the stress patterns in bone trabeculae led to "Wolff's law of bone", a bone transformation concept that explains the biomechanical forces acting on bone to regulate its development, configuration, histologic structure, and physical properties. Among physiologists, Wolff's law quickly became a useful and leading concept and is still basically valid today if it is not overextended, as clinicians in many fields have attempted to do in applying Wolff's theories to specific clinical situations of interest to them. A wider view is presented here, intended to increase your appreciation for the background behind Wolff's law and the many factors involved in attempts to link Wolff's law with various form versus function claims. Wolff's Law continues to raise interest, some limited discussion, or reference in various clinical situations because it has been linked to the tired and worn but trusted concept of many that form interrelates with and is inseparable from function. This biologic truism is that a bone grows and develops in such a manner that the composite of physiologic forces exerted on it are accommodated by the bone's developmental process, thereby adapting structure to the complex of functions. This descriptive perspective, however, has mostly been overstated. IAOM members are familiar with the oftenexpressed view that function dictates form, or even that form dictates function. You may also have heard the claim that if there is a tug of war between muscle and bone, the muscle always wins. How would Down Syndrome be explained, where the characteristic morphologic features of the syndrome result in functions being obligated to adapt to the form involved? Overstatements do not lead to any useful clinical dialogue.

As is well known with long bones of the body, when tension is exerted on a bone at places of muscle attachment, the bone grows locally in response. At such sites of muscle attachment, tuberosities, tubercles and crests will form due to the localized fields of muscle traction. Because many muscles attach near the ends of bones, the epiphyses usually become much larger than the shafts of long bones because that is where muscles apply the most tension and where the bone expands. Not so, however, for bones of the craniofacial area.

The facial skeleton maintains its shape from childhood to adulthood through the selective remodeling of the facial bones; specifically, by apposition and resorption on various bony surfaces. There is no one-to-one correlation between the locations of muscle attachments in the craniofacial area and the remodeling process of resorption and deposition that characterizes facial bone growth. Almost half of all craniofacial bone surfaces where muscles attach are resorptive, not depository, as would be expected with the long bones of the body (Enlow and Hans, 1996). Many muscles of the facial skeleton have widespread attachments onto surface areas, yet within these areas of bony attachment, some areas are depository and some, resorptive, even though these contrasting remodeling surfaces are subject to the same pull by the same muscle and are supplied by the same blood vessels and nerves. While some muscles pull in one direction, the bone surfaces onto which they insert often grow in another direction. An example is the temporalis muscle insertion onto the coronoid process of the mandible. Part of this attachment area on the mandible involves external surfaces that are resorptive. In this example, the function of the muscle involved has not determined the form of the mandible to which it attaches. There are larger issues involved in understanding craniofacial growth control than the influence of muscle pull on bones. As summarized by Enlow and Hans (1996), growth control involves a cascade of graded feedback chains from the systemic down to the local tissue, cellular, and molecular levels, and back again. How each specific, local event interacts and influences specific muscles and functions, is the challenge for future explanations. At present, it is inappropriate to try to explain orofacial myofunctional phenomena and influencing factors in a form and function paradigm of muscles controlling bone growth. The flaw in the full endorsement of Wolff's law of bone transformation, and the simplistic conclusion that function dictates form, involves the presumption that the "law" explains the actual biologic process of developmental control of muscles and bones, that is, how control of development is carried out, rather than simply representing a description of what is happening. One principle omission in the many attempts to apply Wolff's law, and a major flaw of interpretation of it, has been a lack of distinction between the physical forces acting on a bone (its hard part) and forces acting on the osteogenic connective tissues (i.e., those tissues connecting to bone) such as periosteum, growth cartilages, sutures, etc., that actually produce and remodel bone. Such osteogenic connective tissue influences on bone development and transformation are, of course, the basis of Moss's functional matrix theory, which will not be discussed here.

A narrow focus on bone and muscle by current advocates of Wolff's law fails to acknowledge the importance of the connective tissue envelope associated with bone that influences bone development and its transformations during growth. Hence, the belief that many orofacial myologists subscribe to, that function dictates form, becomes a failed attempt to ascribe the biology underlying the discipline to a controlling relationship of muscle to bone.

Of additional interest, many experiments have been carried out in which muscles were severed from their soft tissue coverings, and then artificial mechanical forces were applied to a living bone. Such procedures will always produce some sort of response in the form of the bone and as a result, it has often been concluded, inappropriately, that stress is therefore the principal factor controlling bone growth; or, as translated inaccurately into clinical application, that muscle always trumps bone or that muscle always wins the war over bone. This dichotomy is not merited by a full understanding of Wolff's law. The experiments mentioned above, however, do not eloquently prove such a role for mechanical forces exerted on living bone because many variables exist that cannot be controlled in these experimental designs. Such variables would include vascular and neural interruption, temperature changes, alterations in pH, oxygen tension, and even the duration of the forces applied in an attempt to mirror the clinical situation with muscles, to name just a few variables that are known to affect bone growth.

A fundamental question relating to Wolff's law remains unanswered and still needs to be asked, and that is: Do extrinsic factors that can affect the course of a bone's development also necessarily represent the same intrinsic factors that actually carry out the direct, primary control of the basic histogenic processes of bone growth and differentiation? (Enlow and Hans, 1996). This key question has not been addressed. Nonetheless, there is no doubt that mechanical forces represent one of the "messengers" involved in the activation of osteogenic connective tissues. You may recall discussions of cellular messengers involved in the biology of the periodontal membrane apparatus in convention presentations and in the Hanson and Mason text (pgs. 117-118 if you have the book). What regulates the complex balance of "genic" activities among all of the multitude of cell and tissue participants is a key unresolved issue.

The bottom line with Wolff's law is that it cannot be easily translated to a dichotomous clinical perspective pitting form against function, or vice versa. To try to simplify a complex theory of bone transformation distracts from the worthy goal of explaining muscle physiology related to OMDs. Hence, members are discouraged from making claims linking Wolff's law inappropriately with dichotomous clinical application claims. Also, claims that function determines form, or vice versa, should also be avoided. I hope that this discussion has been helpful and enjoyable. Primary Source: Essentials of Facial Growth. by Enlow and Hans, Saunders, Philadelphia, 1996.