Clin Orthop Relat Res (2011) 469:3077–3078
DOI 10.1007/s11999-011-2041-5

Clinical Orthopaedics and Related Research®
A Publication of The Association of Bone and Joint Surgeons®

SYMPOSIUM: BONE REPAIR AND REGENERATION

The Classic

On the Significance of the Architecture of the Spongy Substance for the Question of Bone Growth: A preliminary publication

Julius Wolff MD

Abstract This Classic Article is a reprint of the original work by J. Wolff, On the Significance of the Architecture of the Spongy Substance for the Question of Bone Growth. An accompanying biographical sketch of Georg Hermann von Meyer and his relationship with Dr. Wolff is available at DOI 10.1007/s11999-011-2040-6. The Classic Article is ©1869 and is reprinted from Wolff J. On the significance of the architecture of the spongy substance for the question of bone growth [Ueber die Bedeutung der Architectur der Spongiösen Sunstanz für de Frage Vom Knochenwachsthu. Vorläufge Mettheilung]. *Centralblatt für die meichinschen Wissenschaften.* 1869;54:849–851.

Editor's Note. This translation was initially performed by Dr. Per K. Amundson, with modifications by Drs. John Skedros and Richard Brand. We took substantial license in condensing some of the cumbersome sentence structure and in using more contemporary terms. Some statements appeared ambiguous and we necessarily interpreted the meanings, hopefully capturing Wolff's intent.

Richard A. Brand MD (✉)
Clinical Orthopaedics and Related Research,
1600 Spruce Street, Philadelphia, PA 19103, USA
e-mail: dick.brand@clinorthop.org

At the Dresden Scientific Conference I presented at the Section for Anatomy and Physiology two preparations of bone, by means of which I could demonstrate, through measurement of inserted wires and rods, the occurrence of longitudinal growth without the participation of apposition from the epiphyseal cartilage.

I was already inclined to come to this conclusion through my recent further study of the discovery by Hermann Meyer of the structure of the trabecular bone, based on complete mathematical precision. I find that the interstitial growth is the sole growth process occurring in bone and that at the epiphyseal cartilage no apposition occurs. Further I find that here neither cartilage is formed nor is marrow produced in the medullary cavity—as documented in my earlier research—and that little cartilage is transformed into bone as—according to my previous research—in the medullary cavity marrow.

As Meyer previously indicated and I have confirmed, each region of the body has a distinct trabecular structure which remains geometrically similar throughout the life span. This geometric similarity is already present in the fetal stage of development. This could have been already inferred. Without a doubt the cancellous bone of the lower extremities is responsible and necessary for bearing static loads; therefore, this arrangement must be present. Since the trabecular structure of the lower extremities is necessary for bearing static loads, this arrangement must be present at least at the age where the child has begun to walk. The geometric similarity would however, as any mathematician would attest, be immediately disturbed by growth, if every single beam of the spongy substance did not participate in the expansion of the bone in the same way. If many more of the new trabeculae participated in deposition to the external surface or to the ends of the bones, they would belong to a different growth period as the trabeculae within the bone.

Let us pursue, individually, the matter of longitudinal growth and thickness growth using specific examples. One considers the Meyer's lines at the proximal end of the lower leg [*crus*] (Reichert's and DuBois-Reymond's Arch.

1867. Plate 18). The locations of the intersections of the trabeculae that can be observed here remain at every age throughout life in a proportional distance from the joint surface. If apposition from the epiphyseal cartilage occurred here, then the intersection location of older subjects should be located in a position much farther from the joint surface as compared to younger subjects. Furthermore, such apposition would have to generate immediately two new intersections where the rising trabeculae of the one side could meet with the trabeculae of the opposite side.

For the thickness growth consider, for example, the Meyer's lines of the femoral head. On the external aspect of the adductor side compressive trabeculae ascend to cross at the border of the head and neck of the proximal femur with the tensile trabeculae from the trochanter side. The inner aspect of the compressive trabeculae, however, curve immediately towards the innermost tensile trabeculae and intersect with these trabeculae already at the level of the lesser trochanter. The external half of cortex of the adductor side is a direct continuation of the femoral neck and supports the neck while the internal half is a continuation of the lesser trochanter and supports bone at the level of the lesser trochanter and crosses the compressive trabeculae. This is demonstrated by a comparison of the complete mathematical agreement of the trabecular arrangements with the compressive and tensile curves of the Culmann crane (Meyer's figure 10). Furthermore, this is demonstrated by inspecting my preparations, on which one can clearly identify even macroscopically, how the compact substance is formed by the condensation (Zusammendrängung der Balken) of the medullary trabeculae.

From this it becomes clear that if, for example, the inner aspect of the cortex of the adductor side were resorbed, the intersecting compressive trabeculae at the level of the lessor trochanter would lose their support and would have to collapse. In addition, the external location of the compact substance can never replace the inner as required by the Hunter-Flourensian Theory, because the external location is not statically equivalent to the inner; furthermore, the external must maintain its position as a support, namely for the intersecting compressive trabeculae in the femoral head.

No one would seriously assert that with the cortex the corresponding trabeculae of the medullary region would drift inwardly and thereby the ascending compressive trabeculae would curve downward as they pass through the femoral neck. Additionally, one could immediately refute the previous statement because all beam intersection angles remain constant at 90 degrees as is shown by drawings of Culmann's crane as well as my dissections; this is contrary to the somewhat incorrect illustrations of Meyer.

Finally it is evident that through deposition of periosteal bone only statically useless and therefore unnecessary bone could be created. As a matter of fact, such bone is not present at any age.