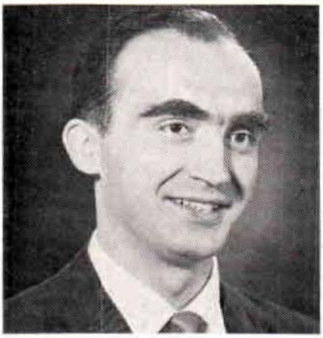
Mechanics of Spinal Bracing as Related to Immobilization



By SIEGFRIED W. JESSWEIN, C.P.O.
Chief Orthotist and Staff Prosthetist
Prosthetic-Orthotic Education
Northwestern University Medical School

The physician diagnoses, prescribes, and treats; the orthotists supplies the tools with which to treat. To avoid error, the physician employs scientific knowledge in his endeavor to correct a disability; the orthotist, therefore, must provide tools which conform to the doctor's treatment approach. It is essential, then, that the orthotist be familiar with knowledge which will enable him to supply apparatuses based on scientific concepts so that the combined effort of physician and orthotist will be an enhancing one.

The roots of success are basic knowledge; therefore, the specific aim of this paper is to state the mechanical principles as they are currently thought applicable to the construction criteria of orthopedic appliances—with particular emphasis on the immobilizing spinal devices.

Whenever confronted with the problem of bracing the spine, the orthotist must ask himself three (3) basic questions, namely—what, why, and how to brace.

What to brace. Inasmuch as every structure of the trunk is subject to pathological involvements, the orthotist must be familiar with the anatomy and kinesiology of the trunk components. He must know that even though only a single component may be affected, the method of treatment consists of bracing a whole unit of which the affected component is part. The body units or areas then which may be braced are the pelvis, sacrum, lumbus, thorax, rib cage, and cervix. In addition to this, any one muscle, or group of muscles (and tendons) may be subject to brace application.[1]

Why to brace. The major objective of bracing is to help to restore to normal or near normal some part of the body which has assumed an abnormal characteristic due to the influence of some force or element. The normal and constant forces acting on any living body are tension, compression, torque, and bending. If any one force or combination thereof exceeds in magnitude the inherent structural resistance of the body to that force, abnormal characteristics will occur.

Of course, forces in excess of the inherent structural resistance of the body are not the only causes of abnormal characteristics. Elements attacking the body internally may cause deviations from the normal or may reduce the inherent structural resistance of the body to an external force. Thus, disease is a cause of abnormal characteristics causing the body to weaken and rendering it more susceptible to deformation and to excessive traumatic forces.

How to brace. The force of muscular contraction must be effectively harnessed, if it is to perform useful work. In the case of bracing these forces must be effectively interfered with in order to permit immobilization. Normally the body is able to utilize mechanical principles to operate certain simple machines inherent in its design; however, when an abnormal condition exists, some of the mechanical principles have to be interfered with or re-directed.

Traditionally, spinal braces have been divided into three (3) categories of function, namely, immobilization, correction, and support. The method of bracing may be found in the definition of each of the aforegoing terms. Although the concept of immobilization is propounded in this paper, for accuracy and completeness the latter two definitions are also given.

Immobilization: to alter the forces acting upon a part so as to render that part immobile.

Correction: to effect a change in alignment of one or more affected parts.

Support: to supplement the action of one or more affected or weak parts.

Thus, in immobilization, normal muscular contractions are interfered with through the altering of forces acting upon the affected parts.

Continuing then with this line of reasoning, it becomes apparent that a spinal brace consists of a complex of induced bending moments—these bending moments being induced through one or more forces acting upon the body.

For clarity of thought and comprehension of the mechanical principles of spinal bracing, several definitions of mechanical terms must be given.

What is a force? "A force is the action of one body upon another producing or tending to produce a change in motion." A force may have the nature of a push or pull and is something measurable by a spring scale.

The action of forces is best expressed by Newton's three laws of motion.

1. A body at rest or moving with uniform velocity continues in that state forever unless acted upon by a force.
2. If a force is applied to a body free to move, the body acquires an acceleration in the direction in which the force acts and proportional in magnitude to the force.

   *F*orce = *M*ass × *A*cceleration
3. To every force there is an equal and opposite reaction.

The above defines what forces are and how they act. In general, most orthotists do not think about these concepts when fabricating spinal braces; however, if at any time they were voluntarily to ignore these concepts, no spinal brace could ever be fitted to a patient.

Of Newton's three laws, the third one describes the mechanism of braces; whereas the first one describes the reason for incorporating the third law in the fabrication of appliances. To illustrate this it may be thought that a functional scoliotic condition continues in that state unless acted upon by a force. Therefore, in order to restrict this condition, a force is applied to the convexly deviating side—this applied force being equally and oppositely acted upon by the opposite structure of the brace. Newton's second law can be recognized by the following example: If a pressure pad were applied to the spine with no opposing pressure, the spine would move and continue to move in the direction of the applied force. This movement would be proportional to the magnitude of the force; or in this case to the force with which the pressure pad pushes against the body.

Generally speaking, however, the orthotist is primarily concerned with Newton's third law; thus, the "three point pressure principle" is nothing more than two forces acted upon by another equal and opposite force.

An integral part of the law of forces is the concept of "bending moments." A bending moment is defined as "the product of the force times the perpendicular distance." It may be expressed in the following equations: $F \times D$, $(F1 \times D1 = F2 \times D2)$ or $\Sigma M = 0$. The latter equation refers back to Newton's third law of motion because it reads, "the sum of all vertical forces (or horizontal forces) must equal zero." In the 3-point pressure system the magnitude of one force (pad) must equal the magnitude of the other two forces (pads). Thus, when bracing the spine for immobilization, the forces acting on the spine must produce moments of equilibrium.

One further concept may be indicated for better understanding of the mechanics of spinal bracing, and that is the concept of "reaction points." "A reaction point is any point against which a force acts." Thus in a typical Chair-Back brace three (3) reaction points are observed. They are:

a. abdomen, anteriorly
b. lower thorax, posteriorly, and
c. lower sacrum and pelvis, posteriorly.

A brace may, however, consist of a complex system of reaction points. For example, in the Taylor brace, in addition to the ones observed in the Chair-Back brace, the presence of axillary straps add the following reaction points:

a. lateral aspects of the pectorals
b. superior margins of the scapulae, and
c. at mid-thorax, posteriorly.

The term reaction point is a very mobile description; yet a very efficient one. In the aforegoing, rather than describing the reaction point with reference to the body they can be described just as easily in terms of mechanical components. This description is dependent only upon the standpoint from which a mechanism is illustrated.

The fallacy of force. Previously the statement was made that spinal braces are a complex of induced bending movements. This, of course, is only partially true. It might be more accurate to say the human body is a complex of induced bending moments. Although this may seem contradictory, it really is not. The following example may clarify this statement.

It is known that an anterior hyperextension brace with tightened worm-gears or straps exerts a force in the anterior direction inducing a bending moment in the sagital plane. However, this force is present only as long as the patient permits his body weight to resist this advancing pad. Since most patients do not care to tolerate this pressure exerted by the pad, they activate their musculature so as to retreat from this force. In other words, the patient activates a "force-avoidance behavior." As soon as the patient has gone through this force-avoidance behavior, the force is transmitted to the musculature in the form of a contraction. Following transmission of this force the apparatus simply becomes a passive structure reminding the patient not to flex or extend the spine (whatever the case may be).

Knowing this phenomenon Doctors Brown and Norton of Massachusetts designed a sacro-lumbar brace which had as its first objective to keep forces (pressures) localized over bony prominences so that prompt and somewhat uncomfortable pressure accompanied forward bending or slumping—flexion of the spine being undesirable in this case. Thus, the successful application of this brace depended upon this force-avoidance behavior.[2]

However, it should not be thought that all spinal braces depend upon this principle, that externally applied forces become transmitted to the musculature; otherwise the correction of scoliosis through bracing would not be possible. In scoliosis the patient has lost a great deal of ability of "directed muscle contracture;" therefore, the pads will retain the force as applied. Of course, some force-avoidance behavior will occur but that will be of reduced magnitude.

In summary, it may be said that it is fallacious to state that all braces do the immobilization. Although a brace may be the initiator of immobilization, the force or moments it induces may become transmitted to some other part, this part doing the actual immobilization. Thus, a force is never lost. A force will always work, but how well it works does depend largely upon the mind.

Immobilizing the spine. Immobilization has been described as "the altering of forces acting upon a part so as to render that part immobile." This term was further defined as complete or effective immobilization. The purpose for this sub-division will be clear when considering the problems of bracing for immobilization.

A recent scientific investigation on the effectiveness of spinal bracing has shown that complete immobilization through external fixation is impossible. Anyone who has observed a patient wearing a Taylor, Bennett, or Knight brace must have noticed a certain amount of gapping at either or both the inferior or superior margins of the brace during sitting or forward bending. This gapping, seeming discrepancy in fit, or seeming improper application of the orthosis may not be necessarily the fault of the orthotist. More often than not it may be due to the inherent mechanical disadvantages of the brace in relation to the body. The inherent mechanical disadvantages may be attributed to the following factors:

1. Discomfort toleration
   A brace can never be applied so snugly as to prevent motion because the force required to accomplish this would be excruciatingly painful to the patient and might upset the normal physiological function of the body.
2. Presence of soft tissue
   A brace cannot be placed directly against bony areas of the body, because all bones are covered with soft tissue which permit a certain amount of sliding and compression. Many of the posteriorly directed forces are exerted solely against soft tissue—meaning the abdomen which offers extremely poor rigidity (mechanical advantage).
3. Transmission of adjacent motion
   Due to the connection of contractile tissue between the lower extremities and trunk any motion occurring in the lower extremities is to some degree transmitted to the trunk. Thus, elimination of motion in the hip joints could appreciably reduce motion in the spine —that, however, is an impractical solution to the problem.

From the aforegoing factors it may be concluded that complete immobilization can never be achieved. But the question may be asked whether or not effective immobilization can be obtained. Effective immobilization may be defined as "to sufficiently alter the forces acting upon a part so as to render that part sufficiently immobile to encourage healing of the part."

How does an orthosis contribute to the healing process and/or prevent an increase in the pathological condition of the patient? The following quotation from the research paper by Dr. Paul L. Norton and Dr. Thornton Brown may serve to answer this question.

"The effectiveness of supports (braces) with respect to immobilization seemed to be related more to the discomfort produced than to the magnitude of force developed between the apparatus and the back."[2] Thus, in effect, these authors support the concept of force-avoidance behavior as promulgated earlier.

With this consideration in mind it becomes evident that brace components must be carefully fitted and strategically located to achieve the effects of immobilization. Thus, it is immaterial whether or not a brace, because of its mechanism, immobilizes the spine as long as that brace induces restriction of motion through an external force, force-avoidance behavior, or the discomfort of the appliances. Effective immobilization then can be said to exist when the brace prevents the patient from executing unwanted motions of a part to favor healing of the part.

It may now be asked, what is the best type of brace for immobilizing any given part of the trunk or spine? Inasmuch as past experience has been puzzling, and research has not yet provided an answer, the following may be considered in the meantime. From the mechanical principles of bending moments, forces, and reaction points it may be promulgated that "a numerical increase of any one of these principles would tend to increase the stability and effectiveness of a spinal apparatus." The spine, particularly the lumbar spine, may be considered as a flexible rod. If a flexible rod is to be kept from bending, the most efficient means would be to enclose it in a snug-fitting cylinder. A cylinder being full of reaction points is capable of inducing more moments or moments of equilibrium than any other device. It may be observed that the original Hessing Corset consisted of a steel frame encompassing the parts to be braced and was completely contained in a canvas corset. A typical Hessing corset, therefore, had incorporated the concept of increased numerical reaction points.

Summary. The aforegoing has been an attempt at re-familiarization with basic mechanical principles as they are thought applicable to the construction criteria of many orthopedic devices. They are principles which apply to all machines. A brace is a simple machine consisting of levers, capable of inducing forces, and bending moments on the human body in order to achieve immobilization of the spinal column and its neighboring parts.

It is to be realized that no new concepts have been formulated, but that the major purpose of this paper was to reiterate basic princples to encourage clarity of thought and a more uniform approach to the problems of bracing the orthopedically handicapped.

References—

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