ASSESSMENT OF SPINAL IMPLANTS UNDER CYCLIC LOADING

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An experimental technique is developed to study the transfer of load through spinal instruments when subjected to cyclic loading. In this study two series of tests are conducted on in vitro calf spines comprising of three vertebrae. First series consists of testing intact vertebrae without instrument cyclically (cross head speed 50 mm/minute). The change of stiffness is studied both in short and long period of loading. Second series of testing are performed on fractured and instrumented vertebrae. In order to asses the power of correction of the spinal instrument the change in the participation factor of the vertebra is studied. For this purpose a model is developed to simulate the burst fracture where the transected vertebral body is replaced by a plastic spacer with a certain elasticity. Furthermore, strain gages were placed to the central parts of the posterior rods. The load carried by this setup is designated as P_S. This model, in the presence of spinal instruments are then tested under the aforementioned loading and the load carried is called as P_{appl}. At the end of tests axial stiffens versus load curves drawn at the end of quasi-static tests supply the necessary preliminary information for the adequate prediction of the behavior of vertebrae (intact and/or instrumented) under cyclic loading. Alıcı and TSRH spinal instruments are compared with respect to the additional stiffness supplied by the instruments and with respect to the participation factor (Participation factor of the instrument = 1 - P_S/P_{appl}) of the instrument. Results of the experiments indicate that Alıcı spinal instrument, under axial cyclic loading can compete favorably well with the other two instruments.

Key Words: *Spine, Biomechanics, Cyclic Loading*

INDRODUCTION

An experimental technique is developed to study the transfer of oad through spinal instruments when subjected to cyclic loading. In this study two series of tests are conducted on in vitro calf spines comprising of three vertebrae. First series (3V series) consists of cyclic testing of three level intact vertebra without any spinal instrument. The variation in stiffness and energy absorption with respect to number of cycles is studied. The study includes also the effect of rate of loading, RL, on stiffness and energy absorption capacity of the vertebrae. The aim of the second type of series i.e. VR (vertebra and rubber) series and VRI (vertebra and rubber and spinal instrument) series is to determine the effect of spinal instruments on the response of vertebra when subjected to fluctuating compressive axial loading.

The assessment of Alıcı and TSRH instruments from the point of view of stability imparted to the vertebra, constitues the final part of the study.

BIOMECHANICAL TESTS

3V-Series

Three intact vertebra are tested up to ~ 1000 cycles (mean load, P_m = 600 N) under fluctuating compressive loading at RL = 50 mm/minute. 600 N mean load corresponds to a body weight during slow walking or relaxed standing if the weight of the body while

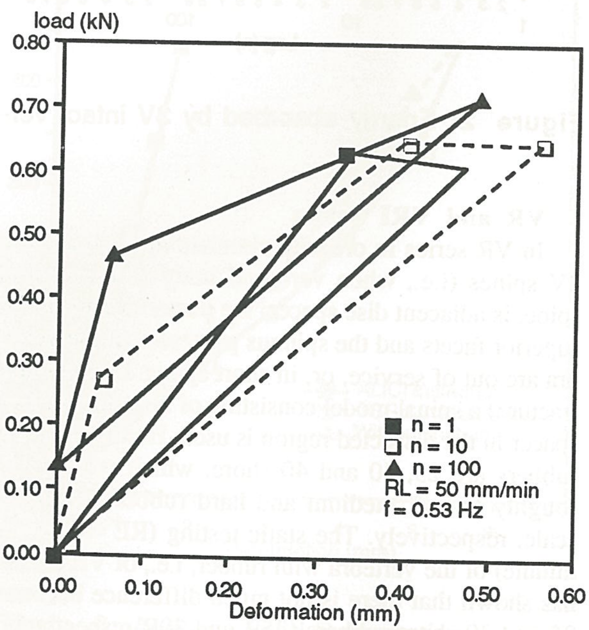

Figure 1: 3V subjected to fluctuating compressve loading (P_m = 600 N)

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sitting is taken to be as 68 % of the body weight [1] of a 60-70 kg human being. Frequency of test was ~0.50 cps, which is twice the frequency that a patient may encounter for 16 hours a day over 4 months [2] and may be considered as a value corresponding to walking [3]. As can be seen in figure 1, even though, at first stiffness of the vertebra increases with load, later as expected it decreases whereas energy absorption increases with the number of cycles (n) in the loading stages (Figure 2). Hysterisis loss follows also this trend, it increases as n increases.

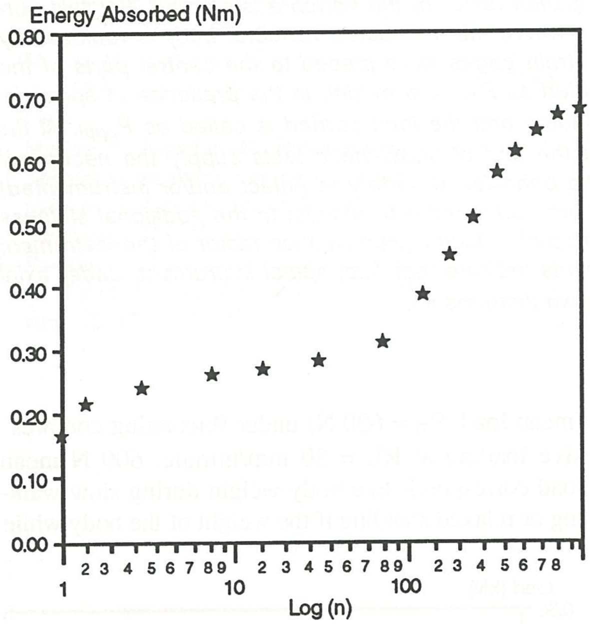

Figure 2: Energy absorbed by 3V intact vertebra

VR and VRI Series

In VR series in order to simulate the destabilized 3V spines (i.e., when vertebral body of the central spine, is adjacent disc spaces, the posterior part of the superior facets and the spinous processes of the vertebra are out of service, or, in short spines having burst fracture) a spinal model consisting of 2V and a rubber spacer in the dissected region is used. Hardness of the rubbers are 25, 30 and 40 shore, which correspond roughly to soft medium and hard rubbers in IRHD scale, respectively. The static testing (RL = 10 mm/minute) of the vertebra with rubber, i.e., of VR model has shown that there is not much difference between 25 and 30 shore rubbers (25R and 30R respectively)

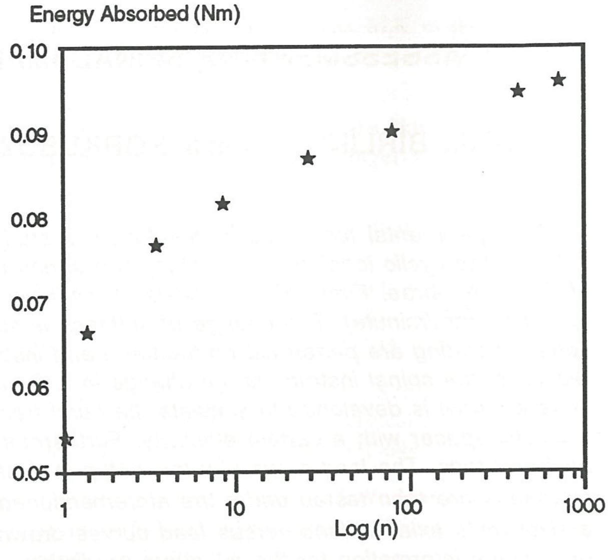

Figure 3: Variation of hysterisis loss with respect to n

from the point of view of destabilization involved in the spine (Figure 4). We have discarded 40R rubber also because, being the hardest rubber available, it would not simulate the worst burst fracture case at all.

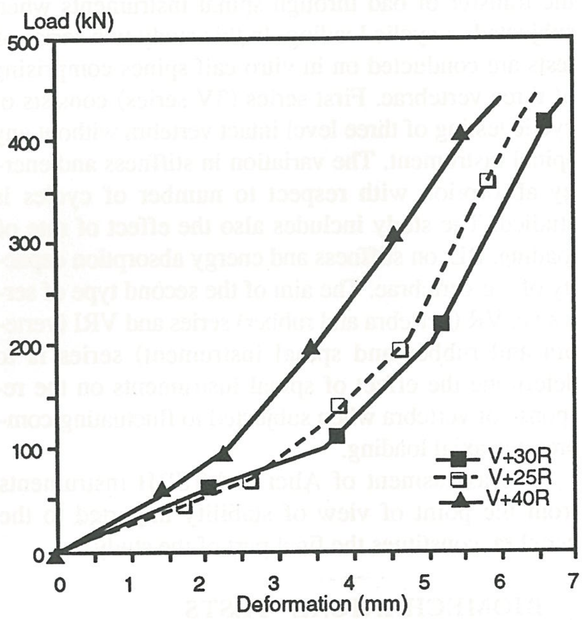

Figure 4: Load-Deformation curves of Vertebra-Rubber specimens

VRI series include static and cyclic testing of destabilized vertebra after the application of spinal instrument (i.e., Alıcı and standard TSRH). First (3V and Alıcı instrument) is tested up to 12 cycles (RL = 10 mm/minute) (0 < P < 450 N) then central vertebra and adjacent disc sphaces are removed and rubber is placed in between the proximal and distal vertebral bodies. The new spine model (i.e., vertebra and rubber) with 25R is loaded three times. 25R is then changed with 30R and (3V and 30R and Alıcı) instrument is tested up to 450 N (~ 68% of the weight of the body in sitting position [2]). Then last stage of the test is repeated in the absence of Alıcı, instrument (Figure 4). As can be seen, Alıcı's contribution to the stiffness of the spinal construct is remarkably high. The increase in the stiffness of the construct is more than 100 %, whereas decrease in the energy absorption is about 70 %.

DISCUSSION OF TEST RESULTS

Contribution of a spinal instrument to the stability of a destabilized spine is usually described by the increase of stiffness of the spinal construct achieved after the application of the instrument. Apart from this contribution, the degree of reduction in the energy absorbed by the spinal construct should also be considered [4]. In figure 6, load-response curves of destabilized vertebra (i.e., V and 30R and Alıcı instrument and V and 30R and TSRH instrument) are displayed. The contribution of Alıcı instrument to the stiffness of the construct is remarkable.

To visualize more clearly the contribution of the spinal instrument, a factor called participation factor (which indicates the role of the instrument in the transfer of load to the uninjured vertebra), P_I, (which is a new a concept proposed here) is defined as

$$P_I = 1 - P_{DV}$$

Here P_{DV} is a factor indicating the participation of the destabilized vertebra in carrying the applied load and is determined from $P_{VR}/P_{applied}$. P_{VR} is the load carried by the destabilized vertebra (i.e., without instrument) and $P_{applied}$ is the load applied to the instrumented destabilized vertebra at an indicated deformation. From figure 4 and 5 it can be seen that P_I for Alıcı instrument ~0.90. This value is very high and it corresponds to ~ 70 % reduction in the energy absorbed by spinal construct compared to the energy absorbed by a destabilized vertebra. In addition, this case can be considered as corresponding to interlaminar motions exhibiting less than 2 % change in length. In [2] it is stated that for length changes less than 10 %, spinal fusion may not be hindered. Further, rapid fusion

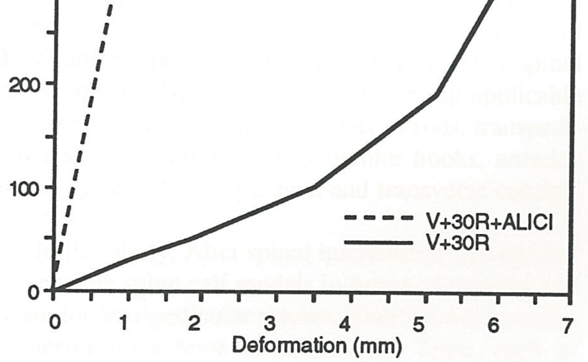

Figure 5: Load-Deformation response of V and 30R and Alıcı sipinal construct

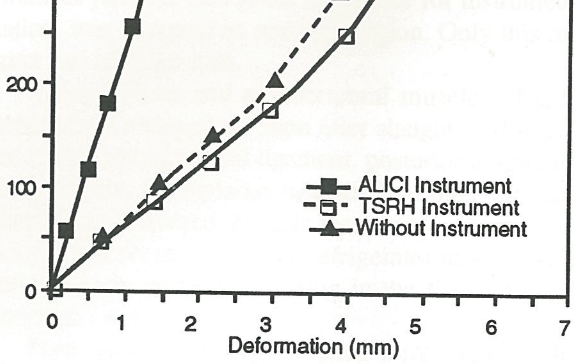

Figure 6: Average Load-Deformation curves

may result when constructs of high stiffness are used but in this case the susceptibility of the construct to sudden loads will be a handicap. In addition, as stated in [5], very stiff instruments may lead to stress shielding of the bone.

CONCLUSION

The number of vertebra models tested in this study is far less than the desired value. Not disregarding this shortcoming a few conclusions yet can be drawn which are the following:

i) In the comparison of spinal instruments, the two criteria i.e., increase in stiffness and decrease in the absorbed energy of spinal construct with respect to the destabilized vertebra, should simultaneously be satisfied.

ii) Since the number of spinal instruments used all over the world (even for a specific destabilization) has a reached a large number, there is a need for a chart which may be helpful to the surgeon in his choice of the instrument. This chart may exhibit the relationship between the load transferred by the instrument (indicated by P_I), energy (or percent reduction in the absorbed energy with respect to unstabilized vertebra) absorbed by the destabilized vertebra, stiffness maintained by the addition of spinal instrument and number of cycles.

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