Remarks on Experimental Techniques

Load application by hydraulic cyclinders or spindle drives

-strain controlled, strain = strain rate * time

-force controlled, force = rate * time

Load cells, strain gauge technique, piezo technique

Elongation measurement device

-inductive

-potentiometer

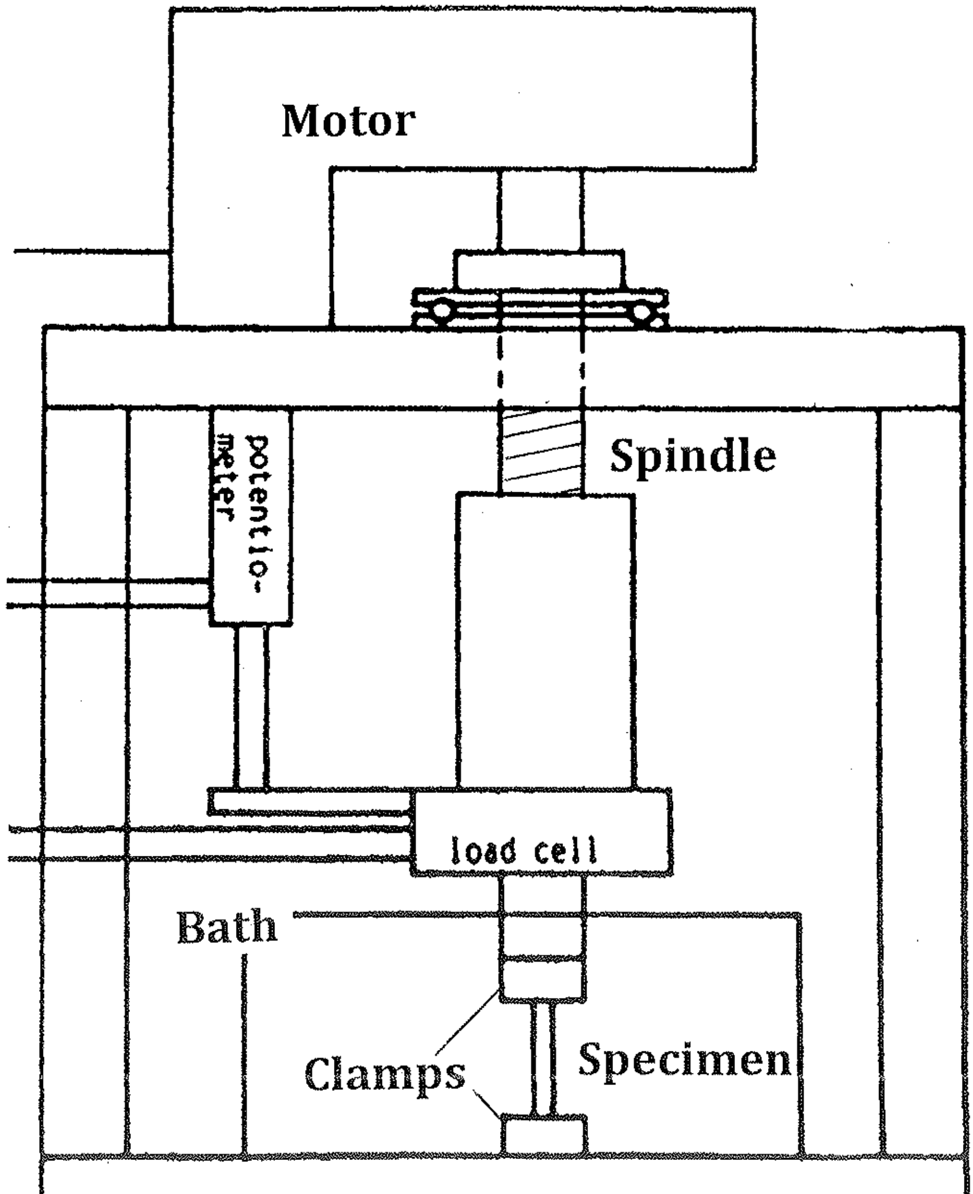
-optical measurements (Video Camera, Interferometric methods)

Clamp the sample to the load axis

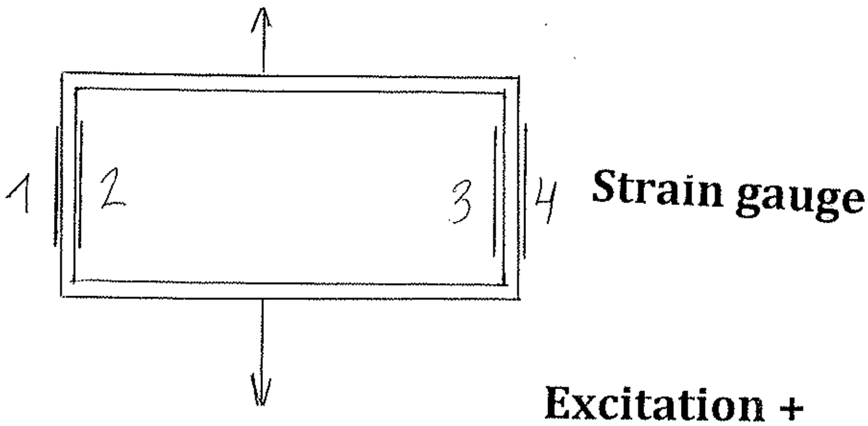
Different methods shown later

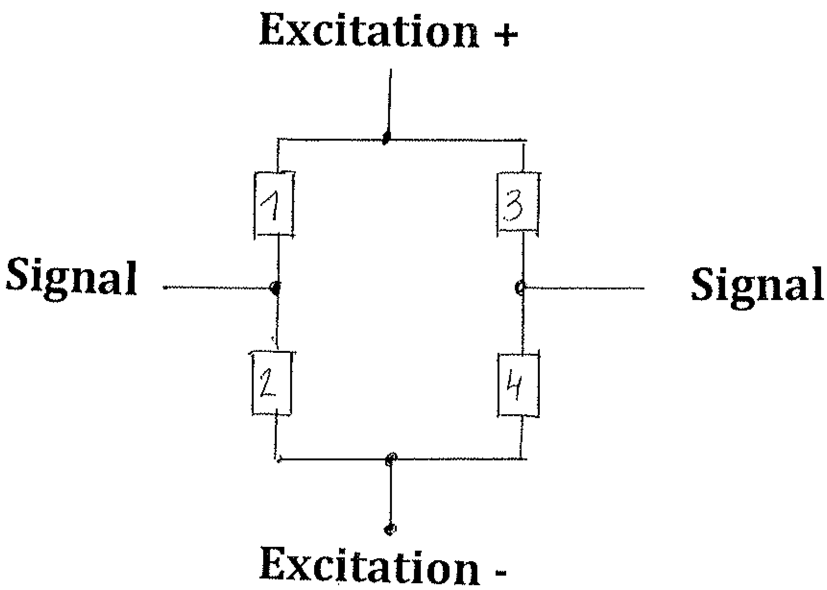
Bath with phophate buffered saline

Schematic graph of a testing device showing the components for tests with bio tissues



Schematic graqph of a load cell based on strain gauge technique





Strain gauges 1,4: R-dR

Strain gauges 2,3: R+dR

Strain = gauge faktor * dR/R

The displacement measurement devices with resolution in μm

Potentiometer ~25μm (clamp-clamp measurement)

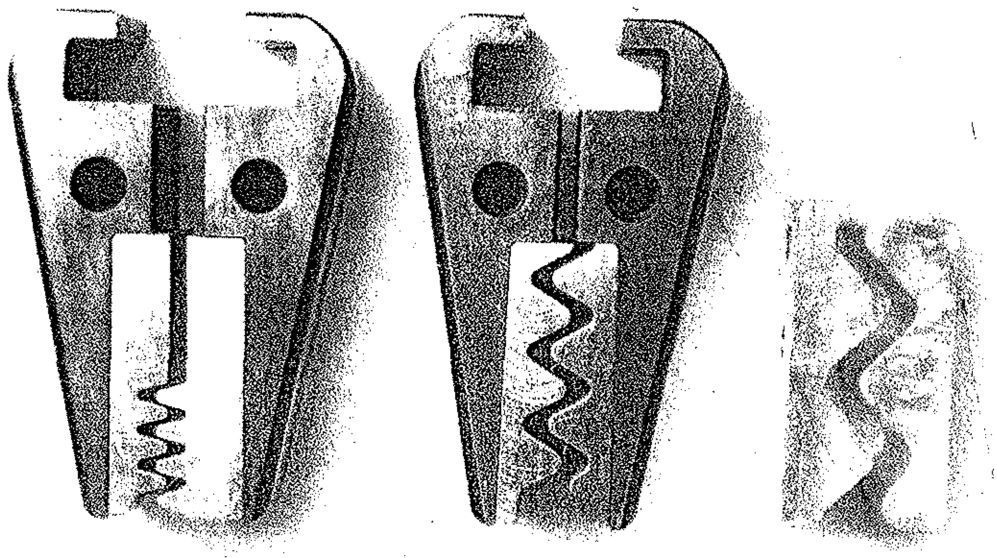
Inductive ~1 μm (clamp-clamp measurement)

Video Camera (depending on the focus of the objective lenses) ~5 μm (field measurement of distance between markers)

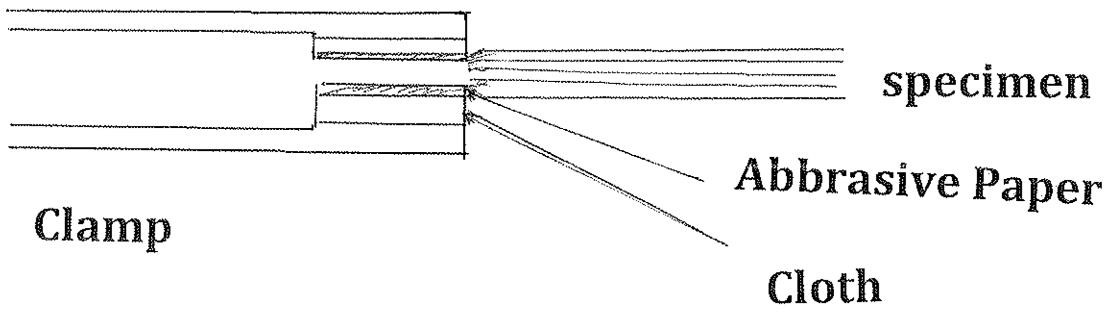
Electronic Specle Interferometry <1 μm (field measurement, the surface of the measured object should reflect light in a diffuse way)

Some methods to fix bio specimens to the load axis

Zig-zag shaped (or better sinusoidal for a soft transition from the metal to the tissue) clamps

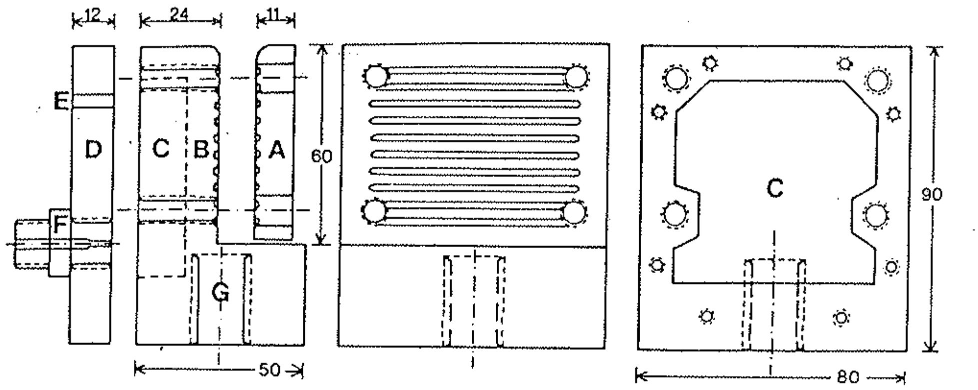


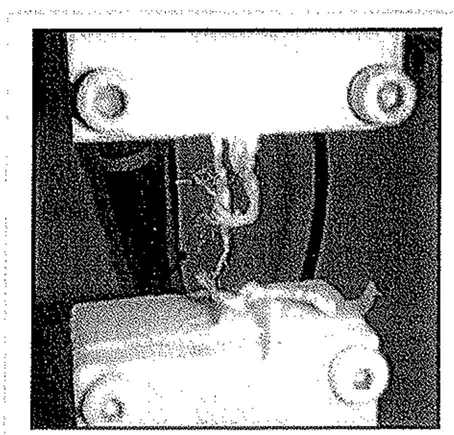
Clamps to which cloth and abbrasive paper was glued. The compressive force has to be applied. This force should not be as strong as to produce jaw-break of the tissue and also not to be too low to prevent the specimen to slip out of the clamp



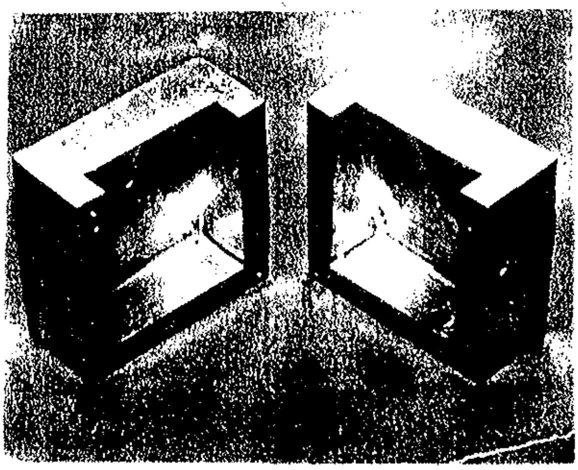
Cryo-clamps

The ends of the specimen are frozen, e.g. by liquid nitrogen, in order to produce rigid ends of the specimens. These end are now fixed as with other materials when mechanically tested.

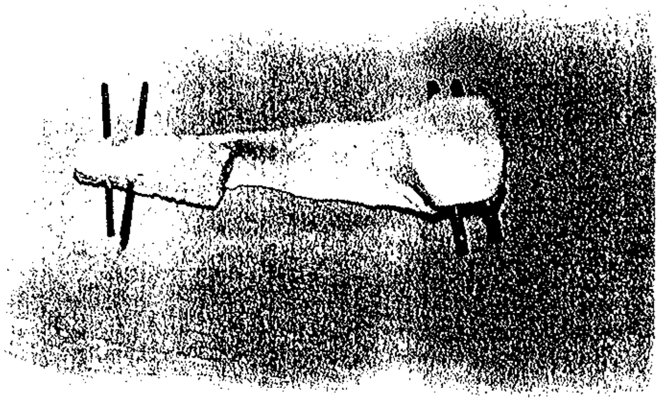




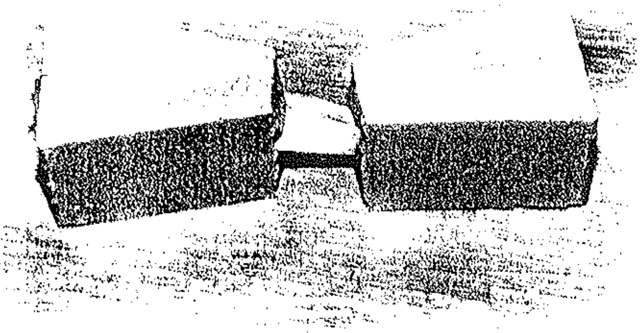
With bone-ligamament complexes we find the method to **fix the bony ends to molds by epoxy resin**



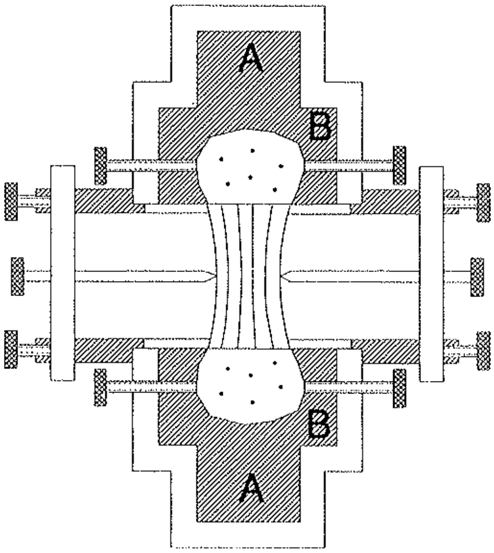
A

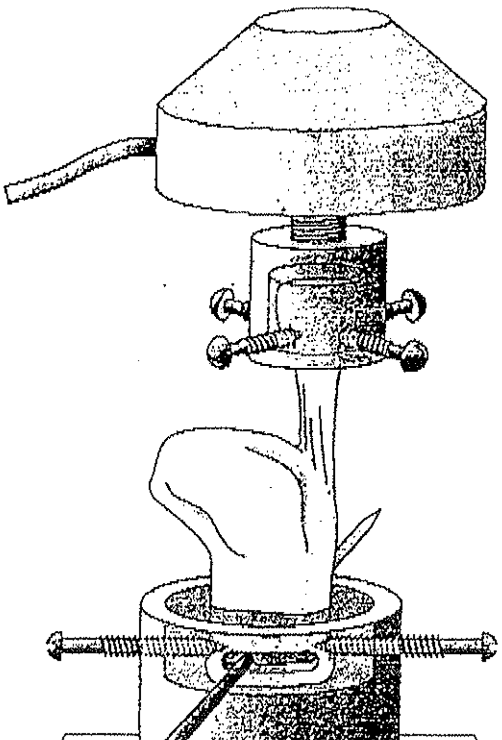


B



Or fix the bony ends with **epoxy resin and /or by screws to molds by screws**





Technical stress is defined by force devided by original cross-sectional area. In case of heterogeneous materials as with ligaments one has to determine the percentage of collagen per unit cross-sectional area (as collagen is the main load bearing element)

There have been reported simple methods like

dry weigth per unit length for collagen rich tissues (rat tail tendons)

It can also be found that the wet weigth per unit area is used.

More time consuming is to determine the collagen percentage of the cross-sectional area by microscopy

Also found is to apply a certain pre-stress to the ligament and use an electronic caliper

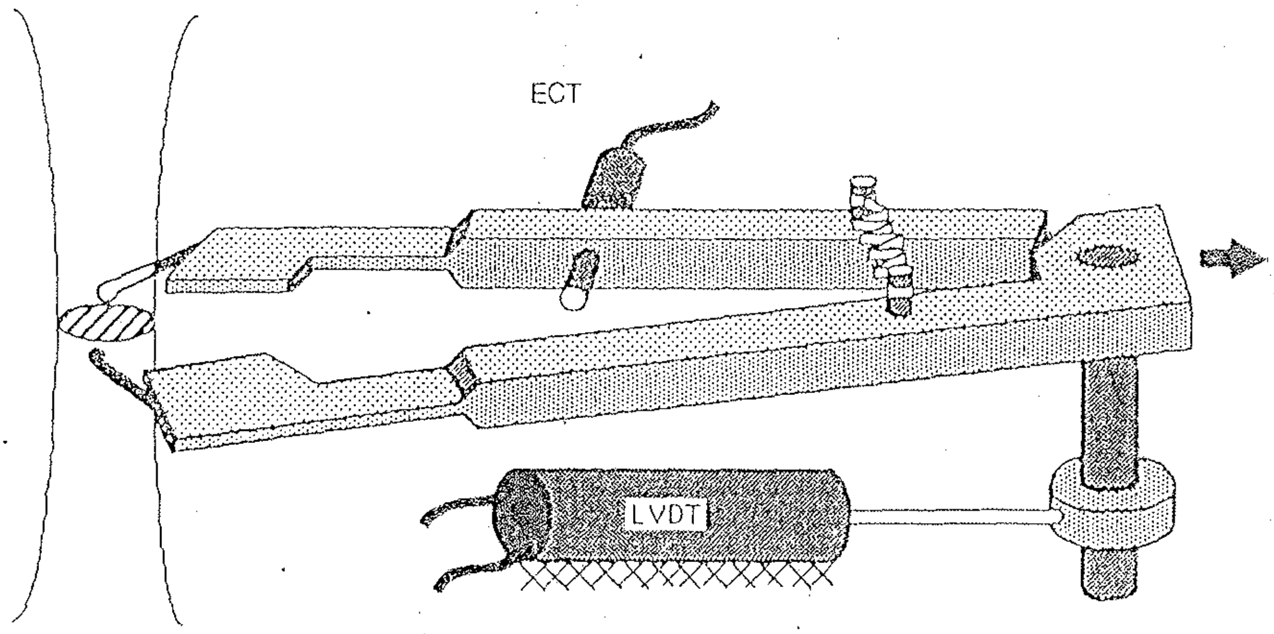


Fig. 1. Schematic representation of TRAC. Caliper is pulled transversely (arrow) with tips tracing the perimeter of a soft tissue specimen. The ECT senses the caliper opening (i.e., thickness). The LVDT senses width with its body stationary and its core moving with the calipers.

Uniaxial strain may be defined by

Change in length per reference length (original length)

The reference length may be seen as the first instant when the specimen takes up the load (dependent of the resolution of the load cell used). At the beginning of the test the specimen will be completely unstrained between the clamps. As the test starts the curvy course of the specimen will be straightened out until a load response is found.

There are other methods as to refer change in length to the final length of the sample

Or to refer change in length to the current length of the specimen

Another method is to mark a reference length at the in vivo configurations (with sutures or a marker) and to stretch the specimen in the testing apparatus until this refence length is achieved.

Strains in case of flat tissues may be defined by drawing a grid and measure displacements of the grid as load is applied to the tissue. Digital image correlation uses bilinear function for the displacement field along the X- and Y-axis,

$$\mathbf{u(x,y) = a_u{*}X + b_u{*}Y + c_u{*}XY + d_u}$$

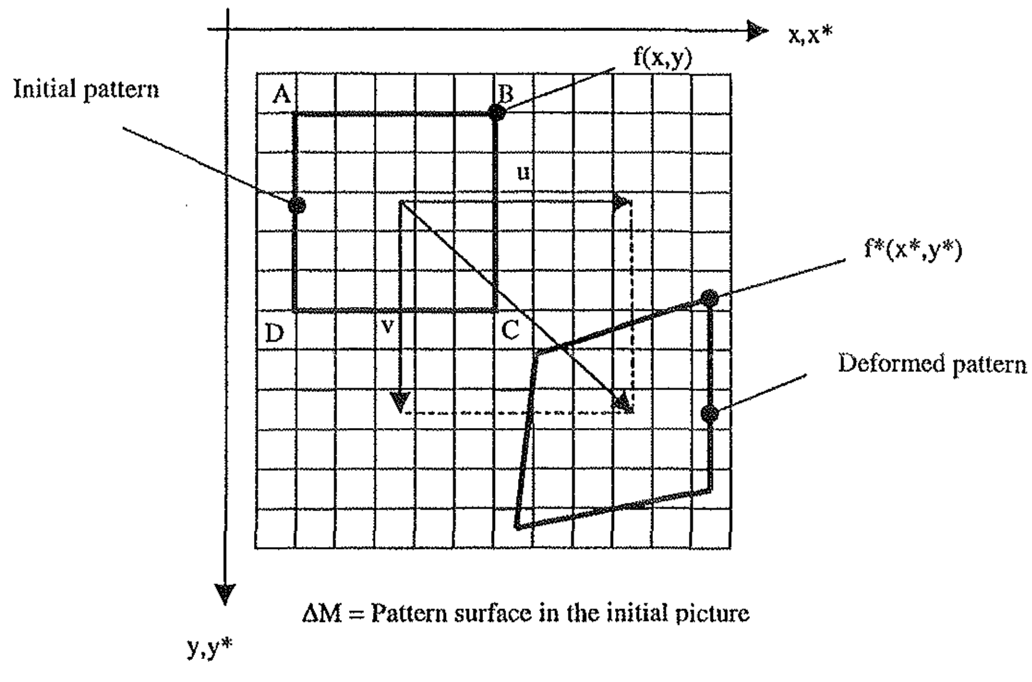
$$\mathbf{v(x,y) = a_v{*}X + b_v{*}Y + c_v{*}XY + d_v}$$

compute the coefficients for the X- ,Y- , and the XY-contribution in order to finally arrive at

$$\mathbf{E_{ij} = (u_{i,j} + u_{j,i})/2 + u_{k,i}{*}u_{k,j}/2}$$

The Green Langrange tensor

$U_{i,j}$ denotes the derivative of the component i with respect to the coordinate x_j.



ΔM = Pattern surface in the initial picture