INVESTIGATIONS ON THE INITIAL AND LATE DEFORMATION OF THE FIBRO-CARTILAGINOUS TISSUE OF THE TEMPOROMANDIBULAR DISK

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INTRODUCTION: The objective of our study was the investigation, for the first time, of the elasticity, hardness and resistance to tearing of the connective fibers in the structure of the TM (temporomandibular) joint disk, with direct applications in dentistry and biomechanics.
For testing we used the Shore-A sclerosope, a modern apparatus used in techniques for the measurement of the hardness of the elastic and elastoplastic materials and adapted by us to the study of human tissues.

MATERIALS AND METHODS: The studied material consisted of 52 pieces (TM joint menisci) obtained from cadavers of various ages, immediately after death, considering the known fact that cartilaginous type human tissues only suffer morphologic alterations several days after death, the cartilaginous tissue being resistant to hypoxia.
In contrast with the opinion of other classic authors who asserted that the age of cadavers does not influence elasticity, we obtained samples from cadavers with ages between 0 years (newborn infants) and 70 years, because we noted (macro-scopically) arthrosic changes in some pieces.
The material was taken in the first hours after death, from patients dying of various diseases, in the University Clinics in Cluj-Napoca, presenting no cranial trauma or blood poisoning; therefore, no post-mortem alterations could have occurred.
The sampling technique is an original one and consists in a vertical 3 cm. incision before the tragus, pulling away of the margins of the incision and removing the soft TM joint parts, for the access to the mandible condyle; the neck of the condyle is sectioned using a Gigli saw, the head of the mandible is extruded using a strong clamp, without compressing the TM joint meniscus. The disk is then extracted using a Kochler clamp, but with much care not to damage the piece, except the one grasped with the clamp, which is not taken under study. After this operation the incision is not sutured, but remains nearly invisible by pulling the margins of the sectioned skin close to each other. If subsequently necropsy is also performed, our incision is superimposed on the necropsy. The piece obtained is examined under a magnifying glass and if it shows lesions it is not included in the study.

RESULTS AND DISCUSSION: After the sample is obtained its length and thickness is measured, and mechanical stress is exerted under the following conditions and observing the following rules:
- The elasticity should be read immediately after the contact of the penetration head. After the application and then removal of the load on the surface of the studied sample a hemispheric imprint remains. In this case the elasticity is expressed by the magnitude of the compression force and the characteristics of the imprint (diameter - depth) left on the studied piece. Unlike applied mechanics, which uses the relation Kgf/sq.cm. or sq.m., due to the small size of the human menisci we used the relation 1

kg.force/1sq.mm surface, which does not influence the results, if the mathematical relations are preserved.

- The determinations are made in 5 points on the upper face of the TM disk followed by 5 points on the lower face.
- The determinations were made in age groups: 0-10 years; 10-20 years, etc., and the mean value of the deformations was used in the calculations.

In a first series of experiments carried out over a one year period, the compression force acted for a short period: from a sudden contact to 4 seconds at most. The deformation obtained did not exceed 0.4 mm. At the sudden contact, the load being removed immediately after its application on the sample, the return of the surface of the disk was sudden and the examination under the microscope revealed no ruptures of the connective fibers or other injuries. If the load acted for 3-4 seconds, the faces of the disk returned within an interval of up to 4", no injuries being produced irrespective of the sex and age of the subject from which the sample was taken.

In the interpretation of the results we considered the main theories about the deformed bodies and the fundamental calculation relations offered by the theories of elasticity and plasticity from which it resulted that the TM disk behaves like an elastic but not plastic material, as will be seen later on.

In another series of experiments carried out simultaneously over a one year period, too, the length of the action of the load was progressively increased to 10, 20 and then 30" After a compression of up to 10" the deformation reached a mean depth of 0.4 mm and the return in the initial state was obtained within about 8".

In all cases a directly proportional relation was noted between the compression time and the time of return to the initial form of the mechanically compressed surface, there- fore no permanent deformations occurred. At a duration of 15"-20" of the compression a transient deformation was obtained.

The initial deformation was of 0.5 mm. After 4-5" from removal of the load, the initial depression (deformation) was reduced to values between 0.1-0.2 mm, for which reason this could not be considered a limit (permanent) deformation.

The total reduction of the deformation occurred after a longer time (15" - 20") and the histologic examination of the compressed area did not reveal morphologic alterations of the tissue. When the action time of the load was increased to 30" an initial deformation of 0.6 mm occurred, being followed by a remanent constant deformation of 0.2 mm. The return time = 20". The difference between the initial deformation and the remanent deformation was indicated with delta (Greek delta).

At a length of the mechanic stress of 30" the first structural alterations occurred, being revealed on stained preparations using various methods (hematoxylin eosine, resorcine-fuchsine, Weiger and Gömöri). The analysis of the preparations revealed dilacerations and ruptures of the meniscal, collagen and reticulin fibers, sometimes with the occurrence of Bischoff hook described in the classical works. However, more frequently cleavage of the collagen fibers (Bratucu, 1977) was noted, this phenomenon being produced when the force or the compression was applied in the sense of their thickness. It results that the TM cartilage behaves in time at the mechanic stresses like an elasto-plastic material, as it results from Fig. 1 (Fig. 1 and 2)

In the last series of experiments the elasticity curve of the TM disk was studied depending on age (see Fig.2). It was found that the elasticity of the TM disk varied inversely proportional with age at a constant compression time. The initial deformation in young subjects was smaller, and the remanent one was reduced (the elasticity of

the disk was greater) than in old subjects where the initial deformation was greater and the remanent one occurred earlier as we got closer to 30".
In the three types of experiments it was found that the TM joint disk behaves like an elastic material up to a duration of 30" of the compression force, after which it behaves like a plastic material, that is, it becomes deformed.
Thus, it enters into the category of elastoplastic materials at a load of 1 kg.f/sq mm applied in man, therefore, very high values if the total surface that can be subject to mechanical stress is considered.

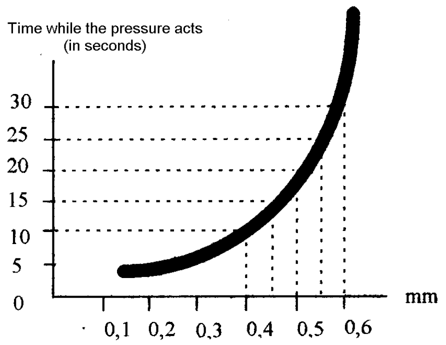

Figure 1. The time variation of the initial deformation (-) to the remanent deformation (-) = Δ (delta) material human TMJ disk

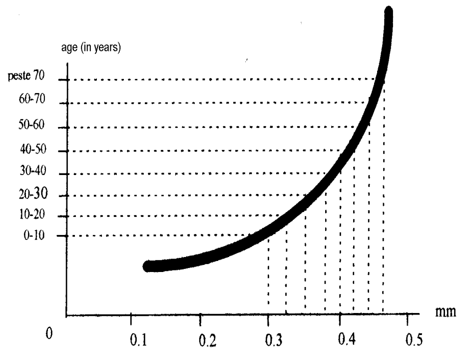

Figure 2. The age related variation of the TM meniscus elasticity (Δ) referred to the initial deformation (compression time = 10 sec.)

CONCLUSIONS:
1. The TM joint disk behaves like a partly elastic - partly plastic material, depending on the magnitude of the mechanical stress and on its duration.
2. Its elasticity varies inversely proportional with age at a constant compression time. This is probably accounted for by the loss of the imbibition water and of its structures, in time conferring it with plastic properties.
3. The biomechanical properties are in agreement with the functional, prevailingly compression stresses.
4. The disk behaves like a true "shock-absorber" for the mechanical stresses, in this sense representing an essential element of the functionality of the TM joint.

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