Summary of TMJ dynamics

Viscoelasticity

The TMJ disc and cartilage exhibit both elastic and viscous characteristics (6). This characteristic property is called viscoelasticity. The viscoelasticity depends mainly on fluid flow through and out of the articular tissues. Immediately after the onset of loading, the small pores in articular tissues impede rapid flow of fluid through the collagen network. The load gradually induces a fluid release from the loaded site by the permeability of collagen fibers (68). This fluid flow results in stress relaxation and creep phenomenon.

Dynamic shear behavior and property

In shear, one boundary surface moves parallel to an adjacent surface. The articular cartilages deform by external shear loading, while internal forces are induced within itself. Shear strain is calculated from the change in length per unit of original length (*Figure S1*). Internal stress is calculated from external force per unit area.

White arrows indicate external shear loading. Shear stain is calculated from the change in length (ΔL) per unit of original length (Lo).

There are two major types of loading on the articular tissue: static and dynamic. Static loading is generated during clenching and grinding, while dynamic loading is during talking and chewing. Under dynamic loading, the articular tissues quickly settle into a steady-state response. To determine the behavior during dynamic loading, a cyclic stress is commonly used for the dynamic tests (69).

According to the viscoelastic behavior of articular components, the stress response to a cyclic strain commonly delays to some extent, and the onset of stress is started with a delay of less than quarter-cycle of loading from strain application (5,6). If the material is purely elastic the onset of strain and stress is at the same time. If the material is purely viscous fluid, the stress response is started with a delay of quarter-cycle of loading.

For viscoelastic materials, the complex dynamic shear modulus G* composes of the storage modulus G' and the loss modulus G". The G' and G" are defined by

$$G^* = G' + iG'' \qquad [1]$$

where $i = \sqrt{-1}$. G' implies the elastic deformation in dynamic shear and is directly proportional to the energy storage in a cycle of deformation. G" shows the viscous deformation in dynamic shear and is also proportional to the average dissipation or loss of energy as heat in a cycle of deformation.

Frictional coefficient

The coefficient of friction, μ, is a constant for the onset of friction between two surfaces. The lower a frictional coefficient, the higher the force required for sliding. The value of the frictional coefficient is defined as

$$\mu = \text{frictional force (F)}/\text{normal force (N)} \qquad [2]$$

The direction of the forces given in this equation is as shown in *Figure S2*.

Fluid film and boundary lubrication

The lubrication system in synovial joints has been identified as boundary and fluid film. The former mainly depends on articular components such as the TMJ disc and articular cartilages, and the latter on a synovial fluid. Boundary lubrication appears when separating the bearing surfaces with nano-level space. It occurs when each load bearing surface is covered with a thin cartilage layer that forms SAPLs layer (47,70). SAPLs are polar lipids and their polar ends bind to articular surface. In healthy joint, the hydrogen connection between SAPL molecules provides highly efficient condensation. Fluid film lubrication involves a synovial fluid by which articular surfaces are separated. Pressurized fluid might contribute to the bearing of normal load with little or minimal resistance to shear force, facilitating a very low frictional coefficient. Furthermore, immediately after loading application, fluid film lubrication occurs with pressurization, motion, and deformation acting to drive viscous lubricant through the gap between the articular surfaces. Typically, surface lubricated by a fluid film have a lower frictional coefficient than do boundary lubricated surfaces.

References

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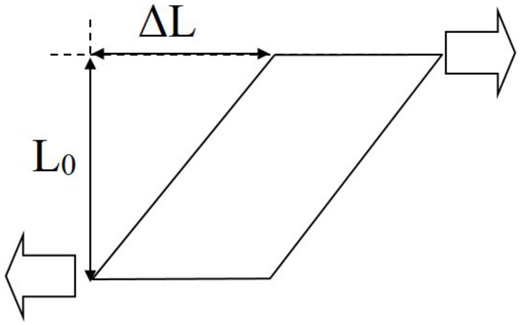

Figure S1 Diagram showing the shear strain.

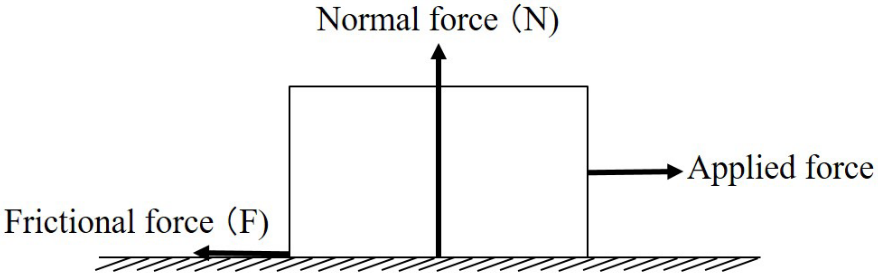

Figure S2 Diagram showing the frictional force.

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