MODELING OF FORCE RESPONSE OF FINGERTIPS IN KEYBOARD STRIKES

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INTRODUCTION

An extended exposure to repeated loading on the fingertip has been associated with many vascular, sensorineural, and musculoskeletal disorders in the fingers, such as carpal tunnel syndrome (Beck-Foehn, 1992) and hand-arm vibration syndrome (Bovenzi et al., 1988). A better understanding of the pathomechanics of these sensorineural and vascular diseases in fingers requires a formulation of a biomechanical model of the fingertips and analyses to predict the mechanical responses of the soft tissues to dynamic loading. In the present study, a model based on finite element techniques has been developed to simulate the mechanical responses of the fingertips to dynamic loading.

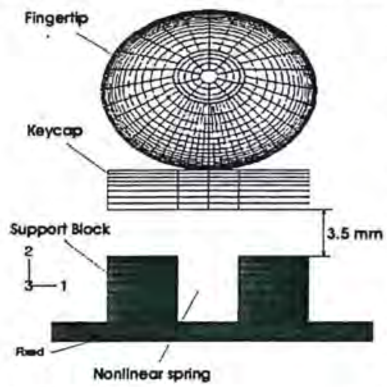

Figure 1: Model of the response of a fingertip to keystroke.

METHODS

The mechanical responses of the fingertip were analyzed using a multi-layered two-dimensional finite element model (Fig. 1). The fingertip was assumed to be composed of a skin layer (representing epidermis and dermis), subcutaneous tissue, bone, and nail. The dimensions of the fingertip were assumed to be representative of the index finger of a male subject. The skin tissue, including epidermis and dermis, was assumed to be hyperelastic and linearly viscoelastic. The subcutaneous tissue was assumed to be a biphasic material composed of a fluid phase and a hyperelastic solid phase. The nail and the bone were considered as linearly elastic. The numerical experiment (Fig. 1) was designed to simulate the experiments reported by Rempel et al. (1994). The keyboard was composed of a hard plastic keycap, a rigid support block, and a nonlinear spring. The contact between the fingertip and the keycap was assumed to be frictionless. A gap of 3.5 mm was considered between the support block and keycap at the undeformed state. The force-displacement relation of the nonlinear spring was determined on the basis of the experimental data of Apple Extended II keyboard with Alps KCM QSIII switches (Rempel et al., 1994). The numerical tests were performed in a quasi-static manner, assuming negligible inertia effects of the mass of the model.

RESULTS AND DISCUSSION

Fig. 2 shows the comparison of the numerical simulation with the experimental data reported by Rempel et al. (1994). The time history of the force response during a keystroke typically demonstrates three phases (Fig.2a): I - keyswitch depression, II - impact of the fingertip on the keycap, and III – compression and release of the fingertip pulp. During the first phase, the finger depresses the nonlinear spring (representing the switch activation), and the deformation of the fingertip is small. A relative large impact force occurs during the second phase, which is associated with the deceleration of the participating masses, i.e. the masses of fingers and arm. Since the effects of the inertia were neglected in the proposed model, the impact force was not predicted in our simulations. The second peak force in the time history is associated, mainly, with the compression of the fingertip pulp, and occurs over a greater time duration than the first force peak. The effects of inertia are negligible during the third phase. The predicted force responses of the fingertip during keystroke phases I and III agree well with the experimental data (Fig. 2).

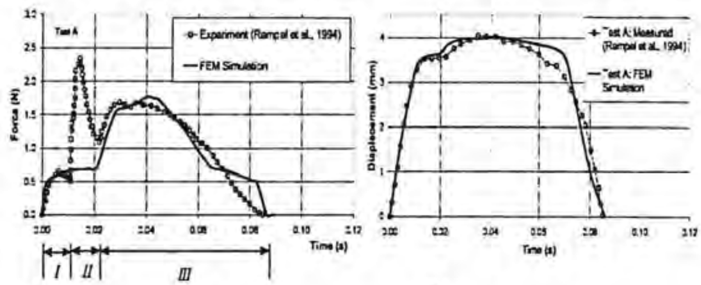

Figure 2: Comparisons of the time-histories of the force response and the displacement excitation of the fingerpad during keystroke obtained in the simulations with those experimental data reported by Rempel et al. (1994). **(a)** Force response of the fingerpad. **(b)** Displacement excitation curves of the arterial bone within the fingertip.

SUMMARY

The proposed model is capable of predicting the time-dependent behavior of the fingertip under dynamic loading, for example, time-dependent force response, energy dissipation, and time-dependent stress/strain distributions within soft tissue of the fingertip. The limitation of the proposed model is that the effects of finger and hand inertia, which participate in the impact interactions between the fingertip and the contacting plate or keyboard, are neglected.

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