contact elements including gap elements and truss elements. The space between the occlusion rim and the mucosa was designed by lifting the occlusion rim 0.1 mm from the mucosal surface vertically in the Connected model. New nodes were connected by gap elements and truss elements vertically.[19] Gap elements in the linear analysis were used to connect two rigid parts. They resist compressive force and tensile force during dynamic movement.

But gap elements are not rigid elements in the finite element analysis system. In order to calculate the dynamic behavior precisely with this analysis, truss elements were applied as the co-connective elements. Following the properties of gap elements and to preventing interference from truss elements, the modulus of elasticity of the truss element was set at 1×10^{-7} kgf/mm^2.

In the Connected model, the lingual element m9 (Figs. 5, 6) showed upward principal stress of 0.2 kgf/cm^2 and upward principal strain of 0.01 under buccal loading at the occlusal surface of the occlusion rim. Under the same situation, mucosa element m9 in the Separated model showed no abnormal dynamic behavior. Furthermore, the amount of displacement of the occlusion rim was similar to those obtained by previous research.[18,20-22] Thus, the Separated model constructed in this study is a useful and reliable design for evaluating stress, strain, and displacement of a denture located on the mucosal surface of the mandible.

Influence of Differential Friction

In the finite element method, friction is an important factor for defining a gap element. However, the amount of friction between the denture base and mucosal surface is difficult to evaluate from clinical experiments. The actual friction that exists at the interface in oral cavity is considered to be very small, because of the intervention of saliva. For defining an appropriate friction value for the model, we used 0.5, 0.05 and 0.005 as friction values for the contact element. To avoid interference, displacement of the occlusion rim on the mucosal surface was attempted. In this study, the model using 0.5 as the value of friction showed irregular movement of the occlusion rim. Furthermore, even when using the defined friction with the smallest value (0.005), horizontal displacement of 0.44 mm and the vertical displacement of 0.28 mm of the occlusion rim were similar to clinical observations.[18,20,21]

Gap and truss elements were employed as contact elements in order to simulate the dynamic behavior between the occlusion rim and mucosa. By applying the contact elements to construct a contact relation between the occlusion rim and mucosa, the components of upward stress and strain in the mucosa were eliminated. The displacement of the occlusion rim was minimized, although it was expected that it would greatly increase when using the contact elements. By means of this simulation, we can more precisely simulate the dynamic behavior between the denture base and the mucosa. This study provides an analytic method for evaluating the relationship of a denture and the mucosa.

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