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ANALYSIS OF THE FIT IN THE IMPLANT PROSTHESIS USING A LASER DISPLACEMENT METER AND THREE-DIMENSIONAL FINITE ELEMENT METHOD

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A precise fit of the implant prosthesis is one of the most important factors in preventing mechanical complications. To analyze the degree of the misfit of implant prosthesis, a modal testing experiment was accomplished. And to interpret the modal testing analysis mathematically, three-dimensional finite element models were established. In the experimental modal testing analysis, with a laser displacement meter, FFT analyzer, impact hammer, etc., natural frequencies of the models with various degree of prosthesis fit were determined after the frequency response function were calculated. In the finite element analysis, the natural frequencies and mode shapes of the models which simulated those of experimental modal testing were computed. The results were as follows:

1. Natural frequencies of the prosthesis-abutment were related to the contact state between components.
2. In the modal testing experiment, the natural frequencies increased from 50μm to 200μm gap and reached a plateau.
3. In the finite element analysis, the natural frequencies decreased gradually according to the increase of the gap size.
4. In the finite element analysis, the mode shapes of model 1 with misfitting prosthesis showed different patterns from those without misfitting prosthesis.
5. The devices including a laser displacement meter used in this study were useful for measuring the natural frequencies of an implant prosthesis which had various degrees of fit.

Key Words
Fit, Modal analysis, Finite element analysis, Natural frequency, Implant

Precise fit between the bearing surfaces of the implant abutment and the prosthetic framework has been thought to be one of the most important factors in ensuring long-term success of implant-supported restorations.[1-3] An inaccurate fit of the prosthetic framework to the implant abutment was suggested to be related with various biologic and prosthetic complications.[3-10] Biologic complications include crestal bone loss around the implants and loss of osseointegration.[3,11,12] Prosthetic ones include loosening of prosthetic-retaining screws and fracturing and/or locking of abutment-retaining screws.[1,3,11,13-19]

Although it is plausible that misfitting prosthesis may threaten the long-term stability of osseointegated implant, clear evidence to support this assumption is lacking.[20] Roberts et al.[21] demonstrated that ankylosed or osseointegrated implants do not seem to become damaged by constant strain. Carr et al.[22] were unable to distinguish an effect from the intentionally applied, measured misfit between implants in the animal posterior mandible. Michaels et al.[23] evaluated misfitting implant frameworks in animal experiment and found no significant clinical, radiographic or histomorphometric evidences of implant integration failure, although bone remodeling around the implant was noted. Jemt and Book[24] correlated in vivo measurements of implant prosthesis misfit and changes in marginal bone level around implants placed in the edentulous maxilla. They reported that a significant statistical correlation between marginal bone level and prosthesis misfit was not found, and the results of both animal and human studies indicated biologic tolerance for prosthesis misfit.

Based on the above-mentioned experiments, misfits of implant prosthesis seem not to be related with bone loss. But, delayed component failure may be caused by misfitting implant frameworks.[10] Many investigators agreed that inaccurate fit can result in the generation of considerable stresses in a screw-retained prosthesis when the superstructure is connected to the abutments and this may give rise to complications and mechanical failure.[25-27] Although the cause of mechanical failure is multi-factorial, it seems that fixed prostheses should have a passive fit to the osseointegrated implant to prevent mechanical complications.[20,28]

If it is assumed that precise fit of the implant prosthesis is significant, the methods of confirming the existence of misfit and measuring the degree of misfit should be considered. There can be two different ways in which to measure the misfit of implant prosthesis. One is to measure the misfit when the implant prosthesis is laid passively on the top of the abutment without deformation of the prosthesis.[29] The other is to measure the force or strain which are introduced when the prosthesis is screwed with the torque as recommended by manufacturers.

In clinical situations numerous methods to assess the fit of a casting have been suggested including alternate finger pressure,[7] testing for rocking of the casting,[30] visual inspection for gaps between the gold cylinders and the abutments,[30,31] tactile assessment of binding and resistance of the screw,[1] the use of radiographs[30,32,33] a disclosing medium,[30,34] one screw test,[1] and relying on the patient' s feedback regarding pain and discomfort.[1,30] Although these methods are very useful in clinic, they depend on the clinician' s senses and subjective decision.

Instruments which can measure the fit of the implant prosthesis have been presented. Tan et al.[35] introduced the coordinate measuring machine in the measurement of the three-dimensional distortion of an implant prosthesis. In the study using the coordinate measuring machine, Mulcahy et al.[36] suggested that the datum plane and the reference system should be set up external to the framework, and emphasized the necessity of consistent references, insisting that the value of the data, in other studies was limited because of the use of the relative distortion model. Numerous papers have been published[24,37-39] since Lie and Jemt[40] introduced the photogrammetric technique. Riedy et al.[41] used a laser videography to evaluate the precision of fit between an implant framework and a patient simulation model. Using these current techniques, it seems possible to achieve results at the micrometer level.[42] However, most of these methods are difficult to use in the clinical fields. Although the photogrammetric technique is said to be the only method that records the fit data intraorally,[42] it require a number of instruments, steps and procedures to introduce errors.[36]

The above-mentioned methods involves measuring the gaps without deforming the implant prosthesis. On the other hand, measuring the gap is different when the prosthesis is screwed on the abutment, seeing as with the torque, the superstructure will bend to close the screw joint when a misfit exists. Although Millington et al.[43] reported that the screw joint failed to close when the fit discrepancy reached 55μm, the magnitude of the gap which can be closed with appropriate torque cannot be expected. The bending of the prosthesis is closely related with the stresses generated when the screw is tightened, while the level of the stresses caused by fit discrepancies is dependent on the size, shape, and location of the gaps; interabutment distance; and the shape, dimensions, and the stiffness of the metal of the superstructure.[43,44] However, the methods of measuring the gaps when the prosthesis is screwed is significant, because the state when the implant superstructures work can be recorded.

Some scientists have attempted to use the vibrational characteristics in implant research. May et al.[45] suggested that the Periotest instrument can be used to quantify the fit of the component interface. However, results of the studies with the Periotest have demonstrated that the Periotest value can be influenced by such factors as: angulation, striking point, and abutment length.[44,46,47] Recently, a noninvasive and nondestructive technique based on vibration theories has been proposed by several authors to assess the implant stability and to monitor the periodontal problems. The mechanical stability characteristics of the teeth after applying a sinusoidal force were discussed.[48-50] Kaneko et al.[51,52] tried to analyze the relationship between the harmonic response of an implant and the condition of the bone-implant interface. In their study, they analyzed the waveform of the vibratory response in the time domain. Elias et al.[53] suggested the theory that the 6-dB roll-off frequency can be used to distinguish between interfaces based on clinically relevant structural characteristics. Meredith et al.[54] used a steady-state sinusoidal force to induce the vibration of implants in vivo and in vitro. But their method was contact analysis which meant that the vibration transducer must be attached to the tested implant. Huang et al.[48] used a modal testing technique to measure the natural frequencies of implants under different boundary conditions. In their study, a transient force was applied by an impulse hammer and the vibration signal was received through piezoelectric microphone without contacting the tested sample.

Natural frequency is a function of the stiffness and the mass of a structure and is related to the boundary conditions of an object.[55] Modal testing, a nondestructive and non-invasive testing technique, can be used to measure the natural frequency of a structure.[56] It has been used to evaluate mechanical properties of dental implants and other tissues by inducing vibration and subsequently measuring the vibratory response.[54] Lee et al.[56] obtained natural frequencies from healthy human maxillary central incisors using a modal testing technique and assessed the influence of the periodontal attachment level on frequency.

Finite element modelling has long been used to analyze the biomechanical properties of various biomaterials and has proven to be an excellent tool.[57-59] It has also provided an accurate mathematical simulation for modal testing experiments. Williams and Williams[60] calculated the frequency response of dental implants with excitation condition using the finite element method and concluded that the dynamic analysis is sensitive and meaningful.

The purpose of this study was to evaluate the modal analysis as a tool of measuring the degree of the fit of the implant prosthesis. In this study the prosthesis-abutment replica complex which had various degree of misfit were analyzed by experimental modal testing and finite element modelling.

MATERIALS AND METHODS

Modal analysis is a process of determining the natural frequencies, damping factors, and mode shapes for a structure. This is usually done either experimentally through frequency response testing or mathematically using finite element analysis. In this study a modal analysis including experimental testing and finite element modelling were used to assess the vibrational characteristics of implant prosthesis.

1. Experimental modal testing

The modal testing analysis is a process whereby a structure is described in terms of it' s natural characteristics which are the frequency, damping and mode shapes.[61] Natural frequency is an important parameter for dynamic description of a structure.

A time response of a vibration can be converted to the frequency domain by performing a Fourier transform of the time signal. The frequency domain representation of this converted time signal is often referred to as the frequency response function. There are peaks in this plot which correspond to the natural frequencies of the system. A frequency response function is the output to input relationship of a structure. Mathematically, it is the Fourier transform of the output divided by the Fourier transform of the input. In this study a frequency response function was measured experimentally and then was analyzed to find the natural frequencies.

A model having precise fits of the implant prosthesis on the abutment replicas was constructed. Three Brånemark Estheticone abutment gold cylinders(DCB 141, Nobelbiocare, Göteborg, Sweden) were put on a flat surface approximately 7mm apart in a straight line. After they were splinted with a pattern resin(Pattern resin, G-C, Tokyo, Japan), wax-up procedures for full veneer gold crowns were done. Splinted crowns were cast with type Ⅲ gold. Then three Brånemark Estheticone abutment replicas(DCB 176, Nobelbiocare, Göteborg, Sweden) were assembled to the prosthesis using gold screws(DCA 075, Nobelbiocare, Göteborg, Sweden) to fabricate the prosthesis which have a precise fit. Then the prosthesis-abutment replica assembly was embedded in the dental stone. The stone base was 50mm high, 20mm wide, and 35mm in length.

After the gap-free model has been made, the discrepancies between the abutment replica and prosthesis were created with thickness gauges. The round, ring-like thickness gauges were inserted into the prosthesis-abutment replica interfaces and the gold screws were torqued to 10Ncm. Six different thickness gauges of 20μm, 50μm, 100μm, 200μm, 300μm, and 500μm in thickness were used to create quantitative inaccuracies at the prosthesis-abutment replica interfaces.

The models were analysed in the following conditions:

Model 1: After the experiment with precisely fitting prosthesis, thickness gauges of 20μm, 50μm, 100μm, 200μm, 300μm, and 500μm in thickness were placed under the left and the center crowns.

Model 2: After the experiment with precisely fitting prosthesis, thickness gauges of 20μm, 50μm, 100μm, 200μm, 300μm, and 500μm in thickness were placed under the left and the right crowns.

Figure 1 shows the schematic diagram of model 1 and model 2.

After gold screws were torqued to 10Ncm with hand contra-angle torque controller(CATC1, 3i, FL, U.S.A.), the stone base was fixed by a metal clamp stand. A transient force was directly applied on the end crown to cause the model to vibrate with impedance hammer(5800SL, Dytran, Los Angeles, U.S.A.). A laser displacement meter(LC2100, Keyence, NJ, U.S.A.) was used to acquire the vibrational response. The displacement was measured on the crown of the opposite end with this instrument.

Both the impulse force and the induced vibration response signals were transferred to a dual-channel FFT analyser(35670A Dynamic signal analyzer, Hewlett Packard, Palo Alto, U.S.A.). Figure 2 represents the instrumentation setting for the experimental modal testing.

The response signal spectrum of a frequency domain was recorded. The data were collected and the natural frequencies were determined. The peak

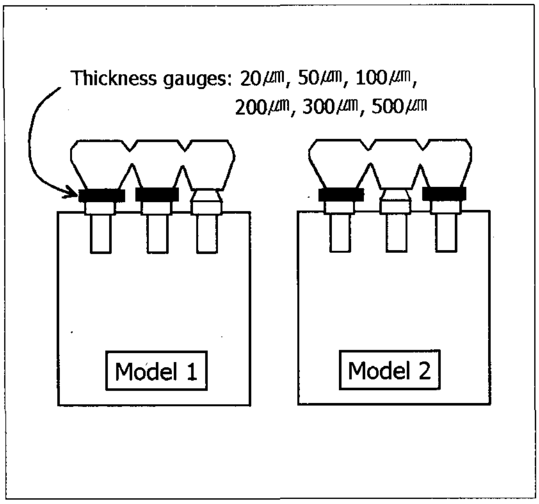

Fig. 1. The schematic representation of model 1 and model 2.

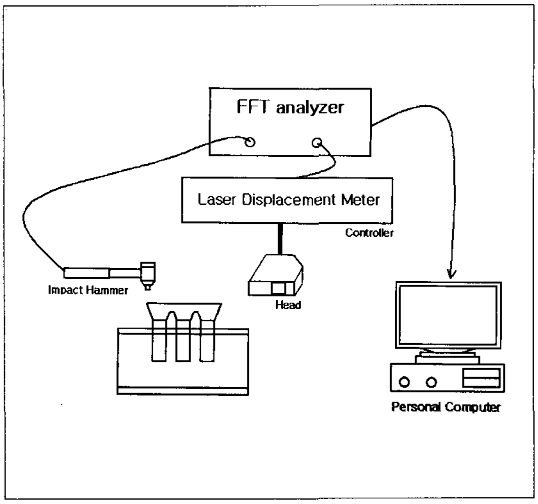

Fig. 2. The instrumentation setting for modal testing analysis.

frequency in the frequency response function plot was regarded as the natural frequency.

2. Finite element analysis

The finite element method enables the investigator to simulate on the computer any physical state by constructing approximate numerical solutions.[62] With eigenvalue analysis, natural frequencies and mode shapes were found in the finite element model. Mode shape is a very definitive pattern of structural deformation at the natural frequencies. This calculation was made without any external force, so the results were intrinsic to the structure. To interpret the modal testing analysis mathematically, three-dimensional finite element models which simulated the modal testing models were constructed(Figure 3).

Each component was designed individually. The geometries of the components were obtained from direct measurements of the components with vernier caliper. The same geometries and the dimensions were used as the experimental modal testing. Every effort was made to simulate the real model used in the modal analysis as closely as possibly except for the prosthesis. A simplified shape of the crowns was modeled for the simplification of modelling. The total number of the models was 13. The model with a precise gap had a total of 15,669 nodes and 14,616 three-dimensional elements. The other models with the thickness gauges had a total of 15,816 nodes and 14,696 of three-dimensional elements. All of the elements were treated as homogeneous, isotropic, and linear elastic.

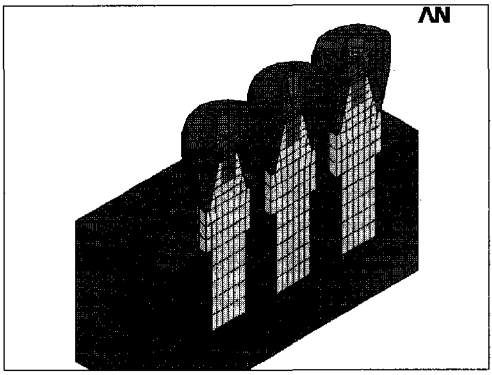

Fig. 3. 3-dimensional model with precise prosthesis fit.

Prosthesis and thickness gauges were assumed to be made of type Ⅲ gold, and gold screws were assumed to be made of type Ⅳ gold. Abutment replicas and thickness gauges were assumed to be

Table Ⅰ. Mechanical properties used in the finite element model

physical properties Materials	Young' s Modulus(GPa)	Poisson' s ratio	Density(g/cc)
Stainless Steel	193	0.27	7.86
Dental stone	145.5	0.3	2.0
Gold(type Ⅲ)	100	0.33	15.5
Gold(type Ⅳ)	99.3	0.33	12.5

made of stainless steel. Values of the mechanical properties were obtained from the previously published studies.[63-67] Table Ⅰ shows the mechanical properties used in this study.

Models were constrained in all directions at the nodes of the underside of the stone base to simulate the fixed condition by metal clamp in the experimental modal testing. Eigenvalue analyses were performed by means of the Ansys program(Ansys, Swanson Analysis, USA), which was run on a personal computer with a pentium Ⅲ 550MHz central processing unit.

After the first and the second natural frequencies of the models were found, the mode shape at each of natural frequency was calculated and recorded.

RESULTS

1. Experimental modal analysis

A plot of frequency against the amplitude for a model with a precise prosthesis is shown in Figure 4. This is a representative plot of frequency against the receptance for the models used in this study. The natural frequency was determined from the peaks.

All of the plots showed a similar patterns. Theoretically, the number of the natural frequencies

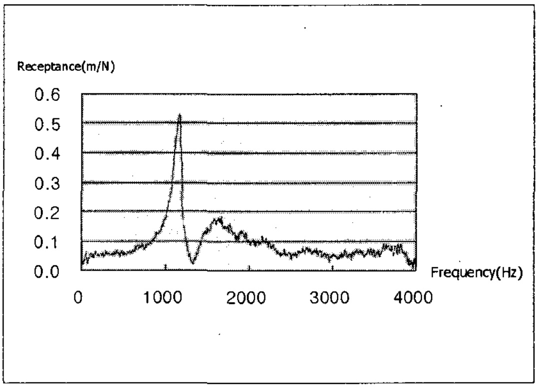

Fig. 4. A spectrum for a precise model in the frequency domain.

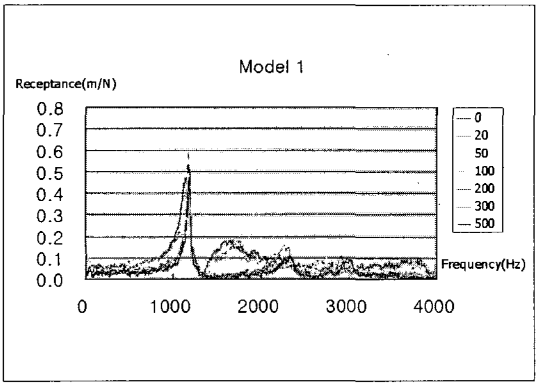

Fig. 5. Frequency-receptance plot of model 1 indicating natural frequencies.

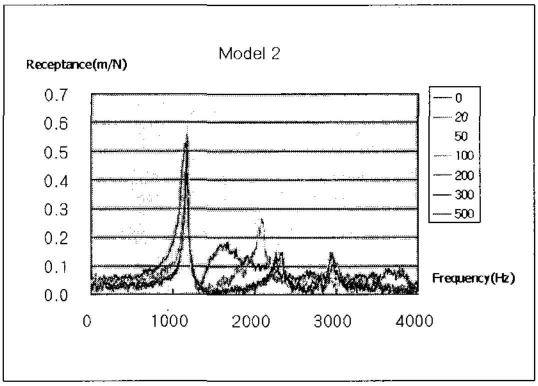

Fig. 6. Frequency-receptance plot of model 2 indicating natural frequencies.

of the models exist infinitively, but only the first and the second peaks were clear. Figure 5, 6 represents the natural frequencies in the models 1 and model 2.

When the prosthesis was fitted precisely, the first mode frequency was 1162Hz. This first natural frequency increased until 100μm thickness gauges were used in model 1. And when the 100μm thickness gauge was used, the first natural frequency

Table Ⅱ. The first and the second natural frequencies of model 1 from modal testing(Hz)

gap sizes(μm) Natural frequencies	0	20	50	100	200	300	500
The first	1162	1168	1176	1192	1184	1182	1180
The second	1638	1795	1944	2237	2336	2320	2314

Table Ⅲ. The first and the second natural frequencies of the model 2 from modal testing(Hz)

gap sizes(μm) Natural frequencies	0	20	50	100	200	300	500
The first	1162	1184	1192	1189	1187	1186	1185
The second	1638	2078	2268	2264	2263	2262	2260

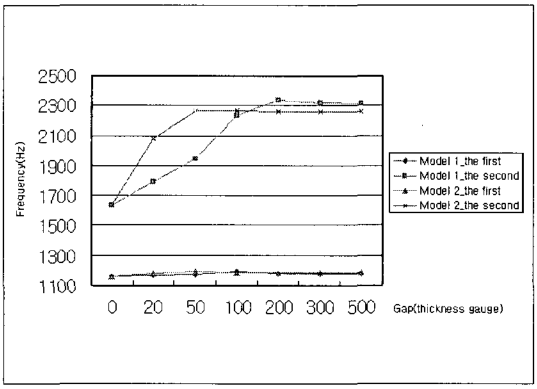

Fig. 7. Natural frequencies in model 1 and model 2 from modal testing.

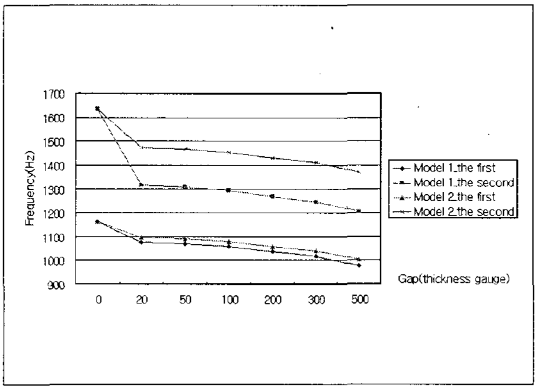

Fig. 8. Natural frequencies in model 1 and model 2 from finite element methods.

Table Ⅳ. The first and the second natural frequencies of the model 1 from finite element methods(Hz)

gap sizes(μm) Natural frequencies	0	20	50	100	200	300	500
The first	1162.3	1076.9	1070.2	1059.3	1038.0	1017.4	977.7
The second	1635.1	1315.1	1306.5	1293.2	1269.0	1246.9	1207.3

Table Ⅴ. The first and the second natural frequencies of the model 2 from finite element methods(Hz)

gap sizes(μm) Natural frequencies	0	20	50	100	200	300	500
The first	1162.3	1096.3	1090.1	1080.0	1060.2	1041.0	1003.9
The second	1635.1	1475.2	1467.7	1455.6	1432.8	1411.2	1371.0

showed the highest value, 1192Hz. When the gauges thicker than 100μm were used, the natural frequencies decreased slightly. At the second mode natural frequencies, the same tendency was observed, however, the highest value occurred when a 200μm thickness gauge was used.

The results of model 2 are presented in table Ⅲ. The natural frequencies in model 2 showed a similar tendency with those of model 1, except for the fact that in model 2, 50μm was the significant gap size in the natural frequency change.

Figure 7 shows the natural frequency changes in model 1 and model 2 from the experimental modal testing. The first natural frequencies in both models showed a similar pattern, and they demonstrated no significant increase or decrease greatly according to the replacement of the thickness gauges. However, the second frequencies increased in both the models in the large scale and reached the plateau at 200μm in model 1 and at 50μm in model 2 .

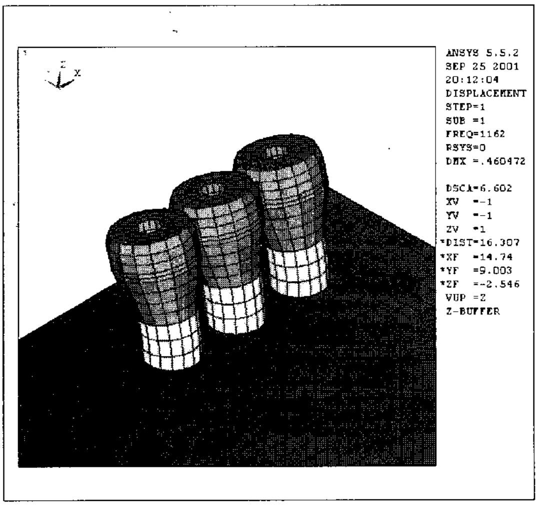

Fig. 9. The first mode shape with precise fit.

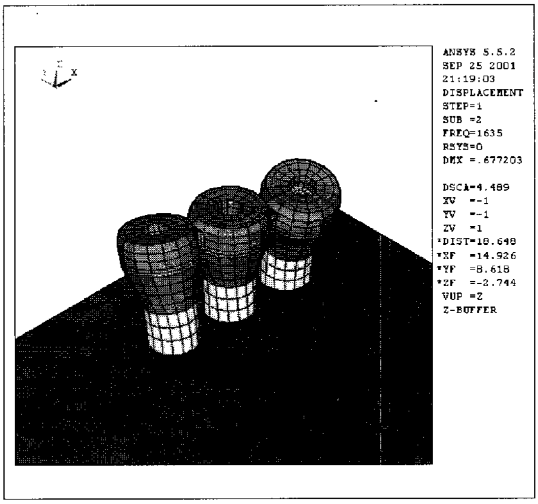

Fig. 10. The second mode shape with precise fit.

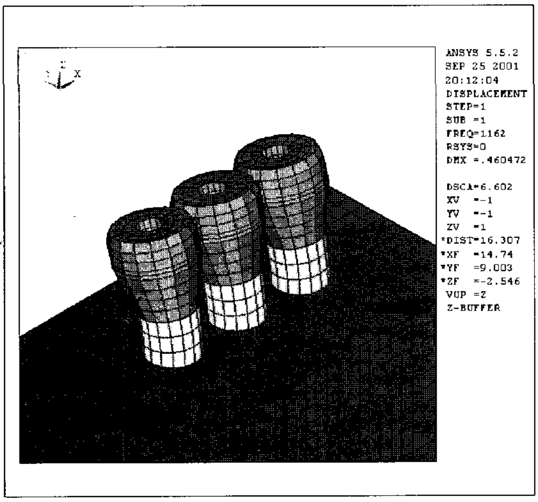

Fig. 11. The first mode shape in model 1 with 100μm thickness gauge.

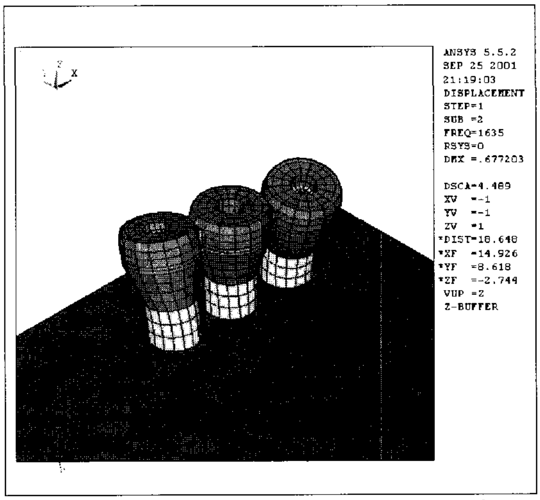

Fig. 12. The second mode shape in model 1 with 100 μm thickness gauge.

2. Finite element modelling

Table IV, V and figure 8 represents the resul-ts of the finite element analysis. Unlike the results of the modal testing experiment, the natural frequencies of all the models decreased as the gap size increased.

Figure 9 to figure 12 shows the representative mode shapes from the finite element analysis. The first and the second mode shapes of the model with precise prosthesis as well as those of model 1 with the 100μm thickness gauge are presented. The patterns of the mode shapes of all the models were similar. However, the part where the misfit exist showed a larger deformation pattern than that in the model with precise prosthesis.

DISCUSSION

Vibrational analysis has been widely discussed in dental and medical fields. Modal analysis is a process whereby a structure is described in terms of its natural characteristics which are the frequency, damping and mode shapes. It was first applied around 1940 in the search for a better understanding of aircraft dynamic behaviour. Until the end of the 1960' s, developments were slow and experimental techniques were based on the use of expensive and cumbersome narrow band analogue spectrum analysers. The modern era of modal analysis is thought to started at the beginning of the 1970' s, based upon the commercial availability of Fast Fourier Transform spectrum analyzers, together with the availability of increasingly smaller, less expensive and more powerful digital computers to process the data.[69]

In the medical field, several authors have proposed techniques based on the vibrational behaviour of bones to assess the bone quality and attempts have been made to use it as an orthopedic diagnostic tool.[68] Jurist[70] measured the resonant frequencies of the ulna, Van der Perre et al.[71] identified different bending vibration modes of the human tibia in vivo, Cornelissen et al.[72] investigated the influence of the surrounding soft tissues, joints and fibula on the vibrational behaviour of the tibia, and Cornelissen et al.[73] discussed the sensitivity of the different modes to fracture healing. Some other investigators found that boundary conditions are the main determinants for resonant frequencies in the long bone studies.[74]

In the dental field, the applications of the vibration technique were mainly focused on the quantitative measurement of bone quality before or at the time of the implant placement, during the measurement of the degree of osseointegration[54] and the assessment of the conditions of periodontal problems.[56]

Natural frequency is the most important parameter of the vibration response when a structure is set to vibrate. It is a dynamic function of stiffness and mass and can reflect the boundary conditions of the structure. In this study by inserting various thickness gauges between the prosthesis and the abutment replica, the boundary conditions were assumed to have changed.

The natural frequencies of the models used in this study could be obtained from the experiment or computer simulation. In this study, both the experimental analysis and the numerical method were used. Nowadays, since technology using computers has developed so greatly, it seems possible to calculate everything on a computer. Nevertheless, it is still necessary to measure the vibrations in the experiment, because the reality is very different and it is worthwhile when considering the reasons for measuring. One reason lies in the fallibility of predictions of stiffness. Another reason is related with damping, since damping alone controls the heights of the resonance peaks.[75] The mechanics of damping is still not understood and claims that damping in normal structures which can be predicted should be treated with scepticism.[75] On the other hand, an adequate mathematical model can be said to be of great importance. Such a model could provide deeper understanding of the experimental observations and perhaps replace experiments in such situations where it would be unethical, very costly or impossible to perform.[55] Furthermore, Williams and Williams[60] stated that the numerical method represents a valid preliminary approach to the assessment of implant osseointegration and is capable of providing a guide to the design of the experimental apparatus for the measurement of the displacement and the frequency in vivo. So it is worth carrying out and comparing both the experimental study and the numerical analysis at the same time.

In the experimental modal analysis of this study, a laser displacement meter was used to measure the frequency response function. In other studies, various instruments had been used. Accelerometer is one of the most common devices used for vibrational signal detection.[76,77] With an accelerometer, acceleration is acquired, so Inertance or Accelerance can be acquired. However, because an accelerometer is a contact device, there is a problem with attaching it to the target. In addition, when the test body is excited, the accelerometer and the test body vibrate together, owing to their physical attachment. Thus, when the overall vibration response is measured, the signal includes a regulatory contribution based upon the construction materials of the accelerometer.[78] Moreover, it is said that the weight of the accelerometer cannot be ignored with regard to the natural frequency assessment.[79] Some investigators used a microphone to avoid the disadvantages of the accelerometer.[68,78] In this study, a laser displacement meter was used. As this device is a non-contact device, it could overcome the shortcomings of a contact device. With a laser displacement meter, the response parameter is displacement. This particular form of frequency response function is called a Receptance. The laser displacement meter used in this study has a 12μm diameter beam spot, a resolution of 0.01μm, and about 30mm of operating distance. It consists of a sensor head and a controller. With the sensor head, the measurements are made and the data is sent to the FFT analyzer by the controller.

In the experimental modal analysis, the natural frequencies were influenced by the changes in the thickness gauges. The results of model 1 were different from those of model 2. Generally the first natural frequency did not change much, but the second natural frequency was altered according to the gap size. These changes seemed to be related with vertical discrepancies. The highest natural frequency value was observed at the gap size of 100μm in the first natural frequency and at the gap size of 200μm in the second natural frequency of model 1. The highest value appeared when a 50μm thickness gauge was used in model 2 which had an intermediate abutment. So when a fit discrepancy was situated at the intermediate abutment, the maximum rate of increase in the second natural frequency value occurred within a 50μm gap. Changes in the natural frequencies can be caused by the difference in the contact area between the gold cylinder and the top of the abutment replica. In this study, the vertical discrepancies made a difference in the contact surface, since only the vertical ones could be created by inserting thickness gauges. The thickness where the natural frequency values reached the plateau, appeared to be the point where complete separation between the prosthesis and the abutment replica occurred. However, at this separation thickness, only the second natural frequency showed a remarkable change. Millington et al.[43] reported that at gaps greater than 55μm, the gold screw did not develop sufficient force to bend the superstructure enough to close the joint. This results was similar to those in this study. However, the fit discrepancy after tightening with gold screw depends on various factors such as the interabutment distance, as well as the materials and the shape of the prosthesis etc. This study has shown that the screw joint failed to close earlier than when it was located at the end abutment when the fit discrepancy was situated at the intermediate abutment. And this results coincided with those of previous study.[43]

Meredith et al.[54] suggested in his study where he measured the resonance frequencies of the implant using a contact transducer that the resonance frequency of the system may be influenced by the tightness of the screw which was used to attach the transducer to the implant as this may change the overall stiffness. And Hwang et al.[48] reported in his vibration analysis on the implant-bone interface that the reduction in clamping torque of dental implant resulted in the lowering of the natural frequency value due to the reduced stability of the tested implants. In this study, the stone base was fixed by a metal clamp with hand tightening and the prosthesis were screwed onto the abutment replica with a 10Ncm torque using a hand torque controller. The degree of clamping the stone base and the accuracy of the hand torque driver would have influenced the results. So the natural frequency values in this study would be changed if the different environments were set.

In this study, the natural frequency value of the experimental modal testing showed a different tendency with those of the finite element modelling. In the finite element modelling the data were calculated mathematically. The density, poisson' s ratio, and Young' s modulus of the materials used in the finite element analysis determined the natural frequencies. The increase in the mass and the height of the prosthesis as the thicker thickness gauges were used seemed to be related with the gradual decrease of the natural frequency value, because the mass and the length of the vibrating object are inversely proportional to natural frequency value. The discord of the natural frequency values between the experimental modal testing and the mathematical calculation shows the limitation of finite element analysis. It may include incorrect material properties, assumptions used in finite element modelling such as homogeneity, isotropy, and linear elasticity of the models as well as the undamped condition. In the experimental modal testing, other factors such as damping would have played an important role in changing the natural frequency value.

CONCLUSIONS

In this study, to analyze the vibrational characteristics of implant prosthesis with various degree of fit, the experimental modal testing and the three-dimensional finite element analysis were used. In the experimental modal testing, devices including laser displacement meter were used to find the natural frequencies of the models. With the finite element methods, natural frequencies and mode shapes were calculated. Within the limitations of study design, the following conclusions were drawn.

1. Natural frequencies of the prosthesis-abutment were related to the contact state between components.
2. In the modal testing experiment, the natural frequencies increased from 50μm to 200μm gap and reached a plateau.
3. In the finite element analysis, the natural frequencies decreased gradually according to the increase of the gap size.
4. In the finite element analysis, the mode shapes of model 1 with misfitting prosthesis showed different patterns from those without misfitting prosthesis.
5. The devices including a laser displacement meter used in this study were useful for measuring the natural frequencies of an implant prosthesis which have various degrees of fit.

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