Implant Placement With a Guided Surgery System Based on Stress Analyses Utilizing the Bone Density: A Clinical Case Report

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INTRODUCTION

With the help of 3D geometrical data from CT scanning as well as computer software for placement planning or provision, guided safe and precise implant placement has become possible based on the available bone volume. However, predictions of the initial implant stability and stress distribution through the implant after integration are also important.

Since multislice CT (MSCT) data have not only geometrical information but also bone quality information based on Hounsfield units (CT value),[1] it is theoretically possible to select an implant placement site with a high CT value to obtain good initial stability as well as create a 3D finite element model for deciding the length and diameter of an implant in relation to stress distribution in a given clinical case.

The purpose of this pilot study was to examine the possibility of utilizing CT bone density data for predicting the initial implant stability and stress around integrated implants with an overdenture abutment using actual clinical data.

METHOD AND RESULT

The patient was a 62-year-old totally edentulous male seeking a mandibular implant overdenture for better stability and higher masticatory performance. After the initial diagnosis and provision of informed consent for both the treatment and this study, diagnostic maxillary and mandibular complete dentures were fabricated for MSCT scanning (Toshiba, Tokyo, Japan). The bone density information in the MSCT data for the mandible was analyzed with simulation software for implant placement site and direction (iCAT version 2, Osaka, Japan) where higher initial stability could be predicted based on the CT value. The actual initial implant stability was measured at its placement with a torque controller.

The MSCT data were also used to construct a 3D finite element model using special software (Mechanical Finder-RCCM, Tokyo, Japan). Pairs of titanium implants with different diameters and lengths (1.8 × 10.0, 3.75 × 7.0, 3.75 × 10.0, 3.75 × 14.0, and 5.0 × 10.0 mm) as well as the mandibular complete denture and average soft tissue thickness data were also constructed. The material properties of the mandibular bone were determined using Keyak's equation.[2] The material properties of the denture base and soft tissue were applied from a previous study.[3]

Analyses of the stress in the bone around the implants under 50 Ncm of load at the right first molar occlusal surface were carried out and evaluated for the cervical, middle, and tip areas of each implant.

Bone density and implant placement site

For the implant placement using the simulation software, the bone CT values were divided into five categories according to Misch's classification of bone quality.[1] High CT value regions were observed on the surface cortical bone area and inside

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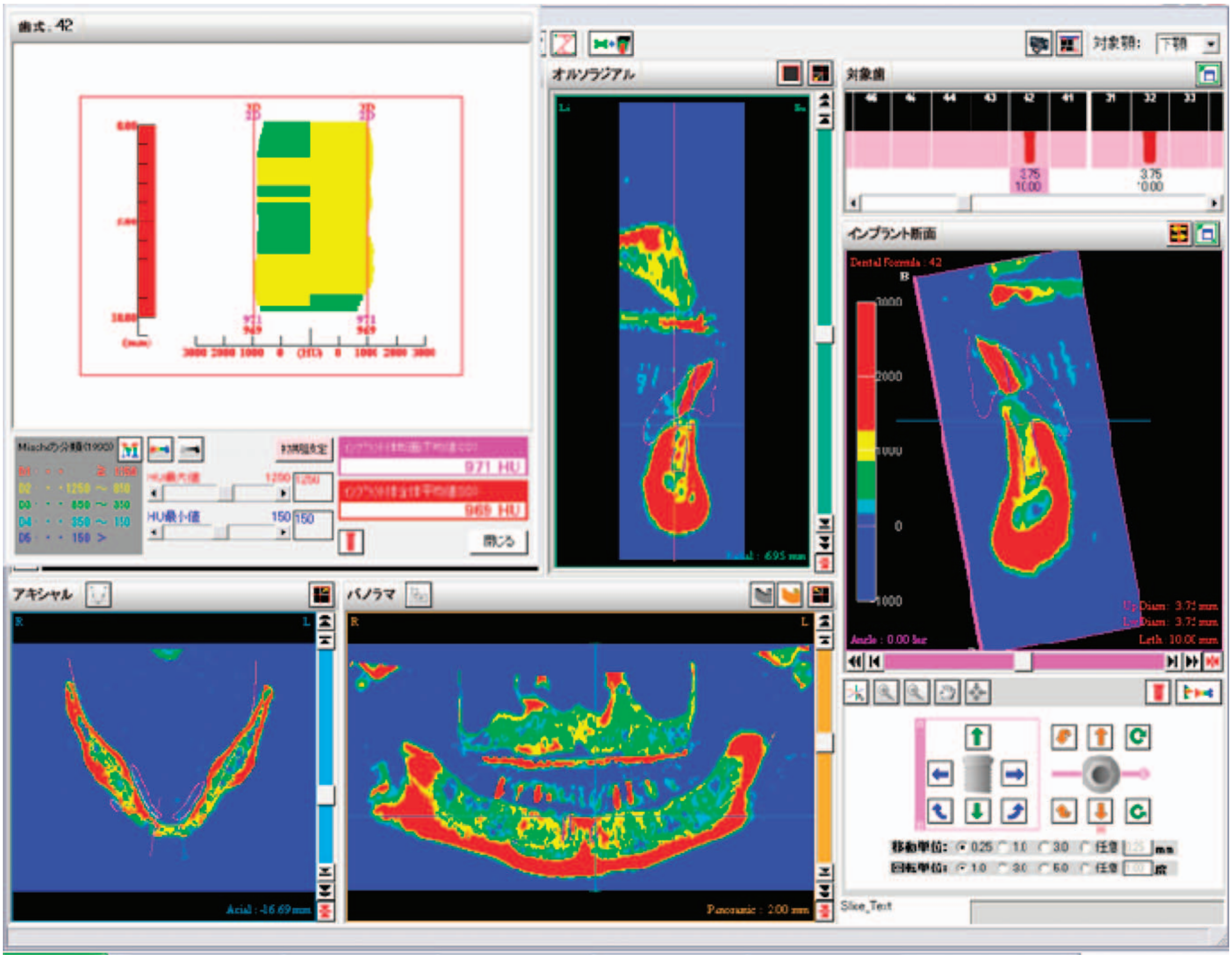

Figure 1. The bone density information in the MSCT data for the mandible was analyzed with simulation software for implant placement site and direction. The red areas have high bone density corresponding to D1 of Misch's classification.[1]

trabecular bone on both sides of the lower lateral incisor region (Figure 1), as previously suggested.[4] Using this information, the sites for the two implants were designated at the lateral incisor region on both sides (Figure 2).

Implant size according to the stress distribution

In the 3D finite element model, the highest stress value was observed at the top part of the narrow implant (1.8 mm in diameter) while the lowest stress value was found in the longest implant (3.75 × 14.0 mm). There was little difference in the stress levels between the implants of 3.75 × 7.0 and 3.75 × 10.0 mm. For the implants of the same length (3.75 × 10.0 and 5.0 × 10.0 mm), the wider implant showed a smaller stress value at the top part of the implant (Figures 3 and 4).

Actual initial implant stability

Owing to the 3D topography of the implant placement area, implants of 3.75 × 10.0 mm were selected and placed. The final placement torque value was 32 Ncm on both sides.

Discussion

Three-dimensional CT data provide valuable information regarding the topography of the bone for deciding implant placement sites with consideration of the safety during surgery and the initial stability. To achieve better initial stability, the implants should be placed into better quality of bone.

Although the use of the CT value for estimating

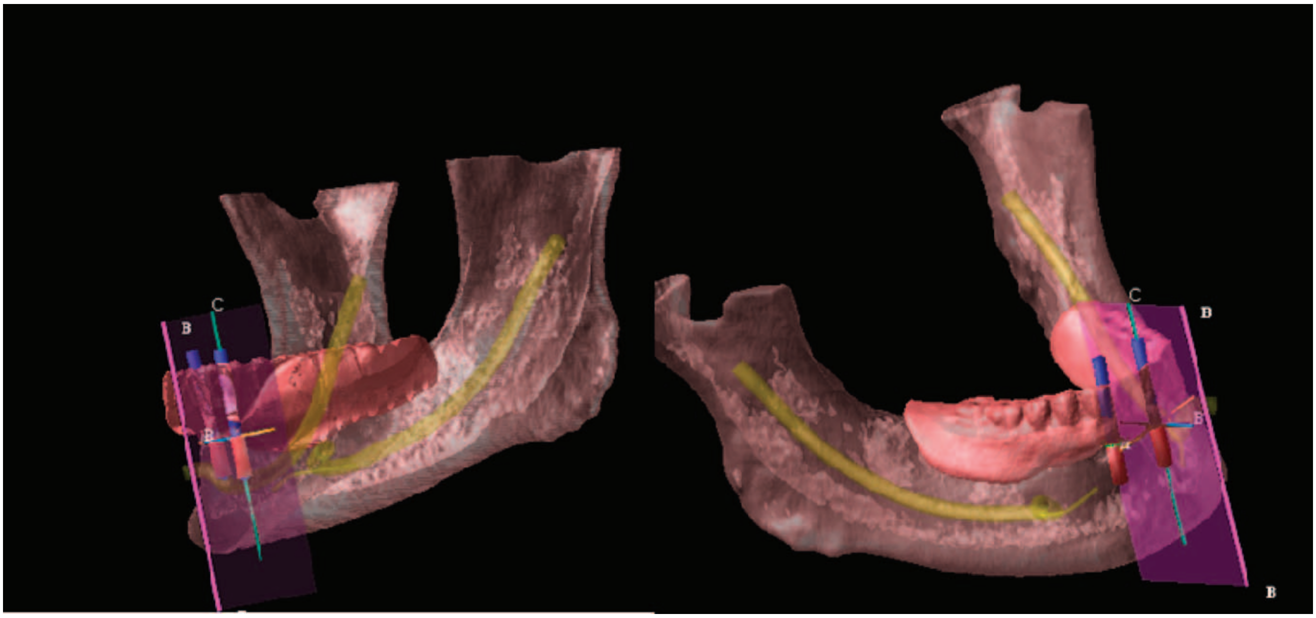

Figure 2. Sites for two implants were designated at the lateral incisor region on both sides.

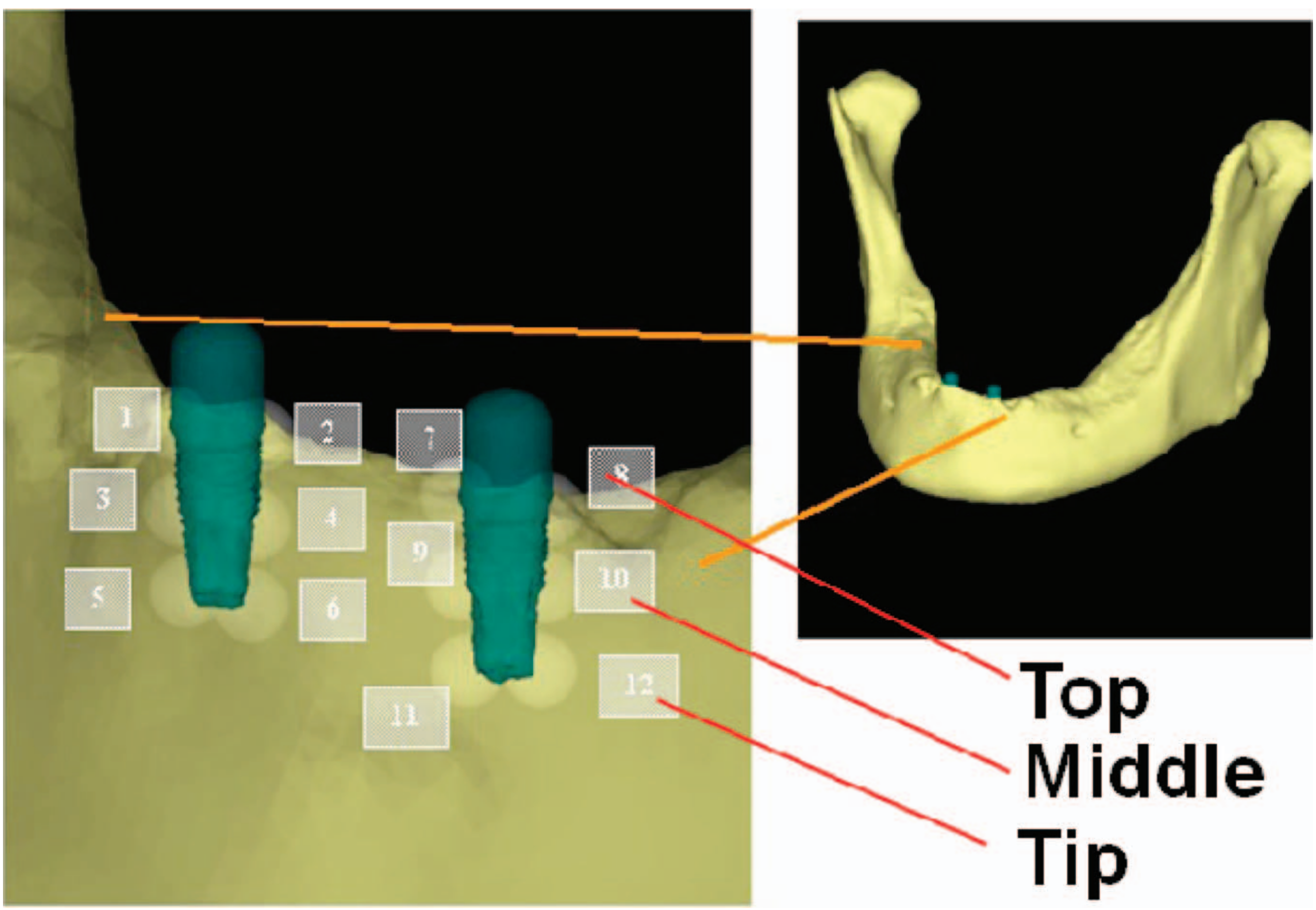

Figure 3. 3D finite element model. Two titanium implants are set at the lateral incisor region, and the stress values are measured in the bone around the implant (top, middle, and tip areas) under 50 Ncm of load at the right first molar occlusal surface.

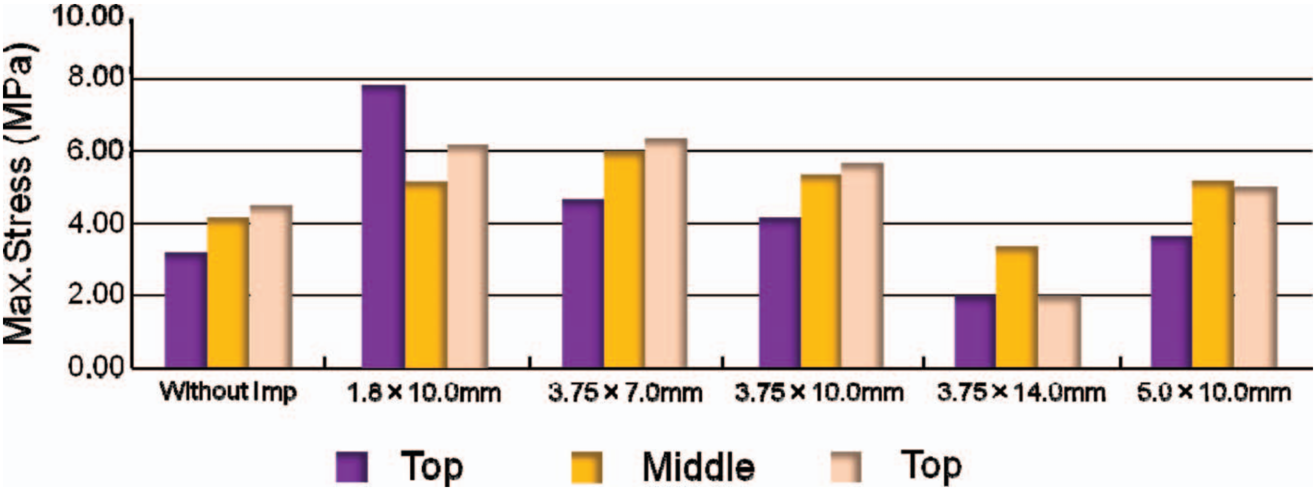

FIGURE 4. Implant size according to the stress distribution. The highest stress value is observed at the top part of the narrow implant (1.8 mm in diameter), while the lowest stress value is found in the longest implant (3.75 × 14.0 mm). There is little difference in the stress levels between the implants of 3.75 × 7.0 and 3.75 × 10.0 mm. For the implants of the same length (3.75 × 10.0 and 5.0 × 10.0 mm), the wider implant shows a smaller stress value at the top part of the implant.

bone quality remains controversial, as classification by Misch[1] and modification by Ikebe et al[5] suggested, it is possible to utilize this value clinically to clarify the relationship between the CT value and the initial implant stability using a resonance frequency method.[6] In this study, a high initial torque value was also obtained where we predicted that good quality of bone would be found.

Regarding the implant size and stress distribution, our results suggested that a wider implant was advantageous. This finding is consistent with Himmlova et al,[7] who indicated that the implant width rather than the length has a significant effect on reducing stress around an implant. Although a long implant has the advantage of reducing the stress, it would also increase the risk of producing heat during the drilling procedure.[8,9] The prediction of stress around the implant under the overdenture using this method is helpful for deciding the implant length and width.

Although there are several advantages with this method, there are still some limitations of this study. Individual morphological differences in bone, soft tissue thickness, different loading conditions, and so on should be evaluated in future studies. Within the limitation of this preliminary research letter, it is suggested that prediction of the initial implant stability is possible using CT data for the bone density, while stress analyses may provide information for the longitudinal stability.

Abbreviations

CT: computerized tomography
MSCT: multislice computerized tomography

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