●原著論文

Evaluation of HA bone graft fabricated by CAD/CAM based on CT simulation

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Abstract

It is popular in these days to use a CT simulation data to determine the bone graft volume in dental implant cases with bone defect and the precise implant placement position. However there has been no report on converting the simulation data three-dimensionally to fabricate bone augmentation materials.

In this study a HA bone graft was fabricated from a sintered HA block using a CAD/CAM technique based on the bone augmentation volume data determined by the simulation data. The HA graft was evaluated by comparing with a resin graft model fabricated by a three dimensional printing (3DP) method based on the same simulation data.

The HA bone graft by CAD/CAM and the resin bone graft by 3DP was well consistent each other in the shape , size, and adaptability.

Keywords: HA bone graft , CT simulation, CAD/CAM, 3DP

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1. Introduction

Implant treatments have greatly progressed along with the development and improvement of CT and simulation software. It is now possible to observe the three-dimensional information of the bone on the software. Flapless surgery is possible with guided surgery using surgical guide based on the simulation data. It is less invasive for the patients and makes surgery easier for the operators [1-8]. Advancement of CAD/CAM technology has brought big changes in dentistry and quite a lot of prostheses are manufactured using this technology Figure 1 shows a surgical guide designed by a simulation soft and figure 2 is an oral cavity of a guided surgery. Figure 3 is the provisional restoration after operation and figure 4 and 5 are the panorama X-ray photo, final prosthesis, respectively.

For implant cases with bone defect, bone augmentation is necessary to obtain implant placement position and aesthetical improvement. Block bone transplant using autologous bone or GBR method using granular bone substitutes and multiple membrane are commonly used bone augmentation methods. However it is difficult to recreate the ideal form because of the difficulty in predicting the absorbed amount loss of the grafting

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material over time and difficulty of the surgery itself.

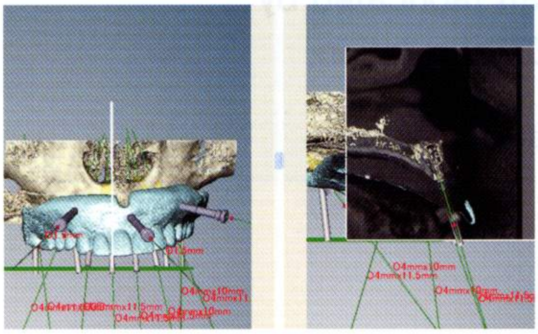

Fig. 1: Designing a surgical guide based on CT simulation software

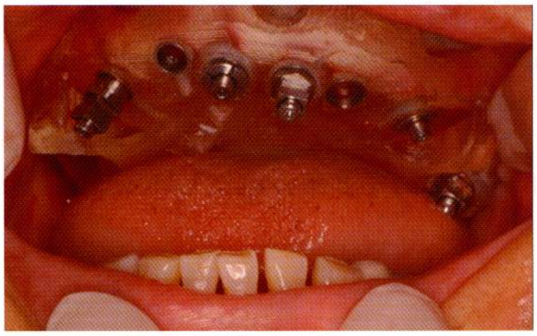

Fig. 2: Oral cavity the guided surgery using the surgical guide made by 3DP

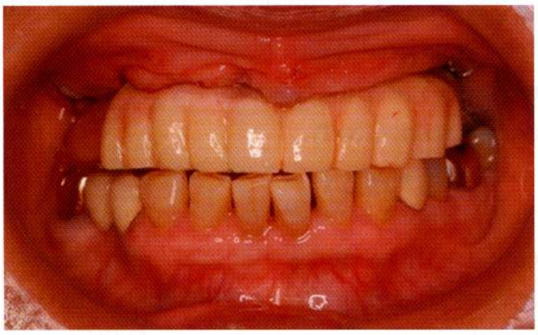

Fig. 3: Installation of provisional restoration before operation made on model material

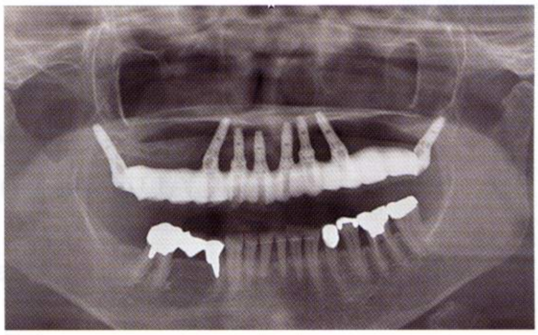

Fig. 4: Panoramic X-ray photo after installation of final prosthesis

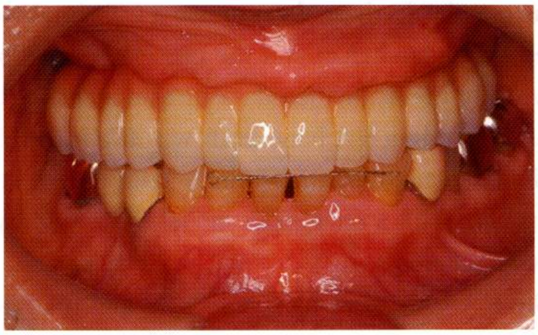

Fig. 5: Oral cavity of the final prosthesis made by CAD/CAM technology

In this study HA block was successfully made using CAD/CAM technology based on the bone augmentation volume data for the bone defect region worked out by simulation software for an implant case with bone defect in buccal #20 and #21. This paper reports its summary with accuracy validation.

2. Materials and methods

1) CT apparatus

3DX multi image micro CT (FPD8) manufactured by Morita Co. was used under the condition of diameter 60×60㎜:125μm.

2) Simulation software

SimPlant® manufactured by Materialise Dental Co. was used.

3) HA block

HOYA Technosurgical Co. apaceram-U5 (30x40x10mm, porosity 50%) was used.

4) CAD/CAM

Based on the bone augmentation volume data, HA block (hereinafter HA bone graft block) was shaped by CAD/CAM technology using processing machine (GM-1000) at GC processing center.

5) Form and compatibility

Resin bone augmentation model and bone defect model were made by rapid prototyping using 3DP (three dimensional printing) and were compared in form and compatibility three-dimensionally with HA bone graft block.

6) Contamination

After shaping out the block with CAD/CAM (processing machine, GM-1000 at GC processing center) contamination test was conducted by EDX (Energy Dispersive Fluorescent X-ray Spectroscopy) by Tokyo Dental College.

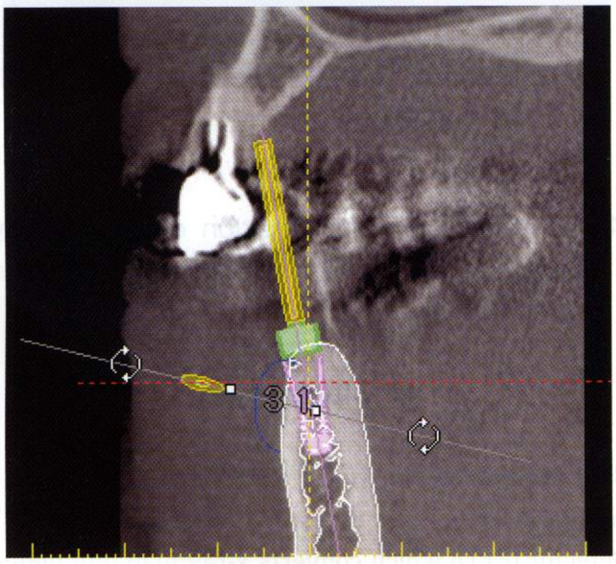

Fig. 6: CT image to determine implant placement position and bone graft volume

3. Results

1) Designing with simulation software

Simulation software was used to work out the bone augmentation volume needed for the bone defect region and to design the precise implant placement position (Fig 6, Fig 7, Fig 8) and fixation tack holes onto available bone. In order to avoid contact of the bone augmentation material and the implant, the implant access holes on the bone augmentation material were designed slightly bigger than the diameter of the implant.

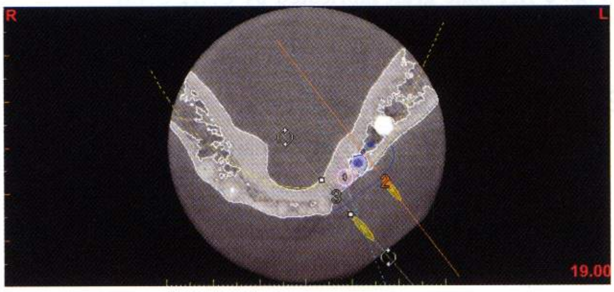

Fig. 7: CT image to determine implant placement position and bone graft volume

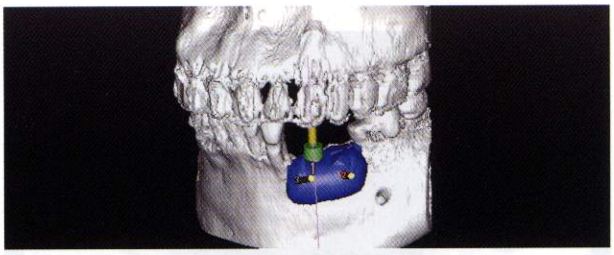

Fig. 8: CT image to determine implant placement position and bone graft volume

2) HA block

HA bone graft block was shaped out using CAD/CAM processor: GM-1000 (Fig 9).

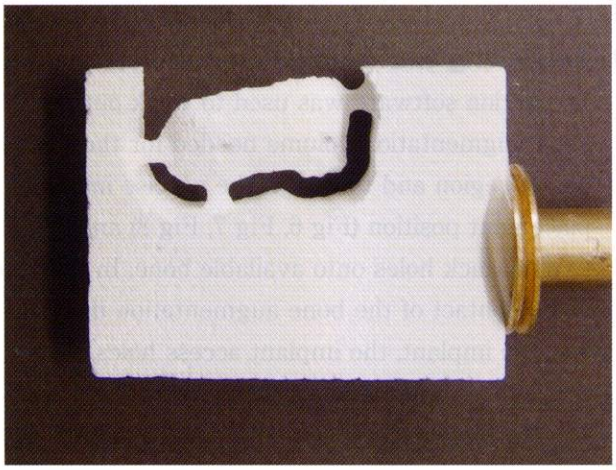

Fig.: 9 HA bone graft fabricated by CAD/CAM

3) Form and compatibility

HA bone graft block and resin bone augmentation model made by rapid prototyping using 3DP looked grossly resembling in comparison (Fig 10). Also their good adaptability was confirmed on a resin bone defect model (Fig 11(1),(2)).

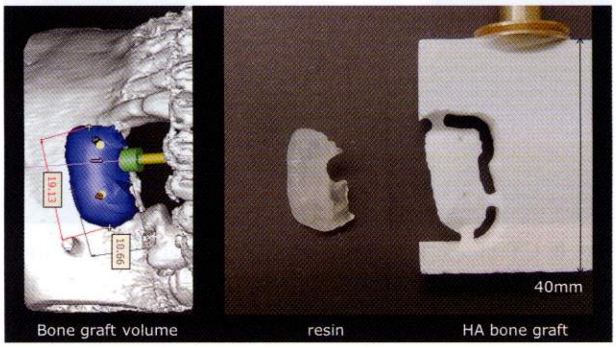

Fig.: 10 Comparison of the HA bone graft by CAD/CAM and the resin bone model by 3DP based on the same simulation software

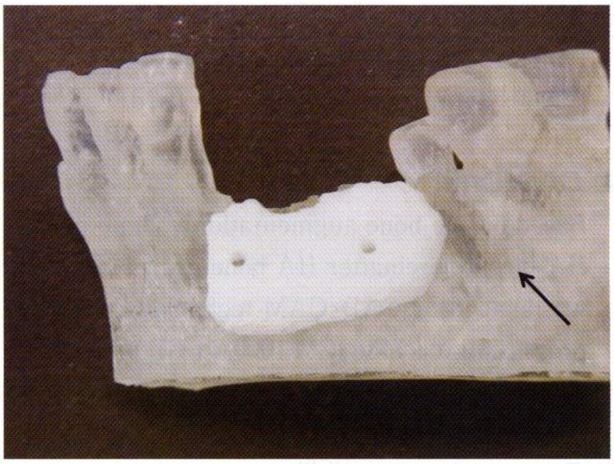

Fig. 11: (1) Adaptability of HA bone graft and resin model (arrow) from the side.

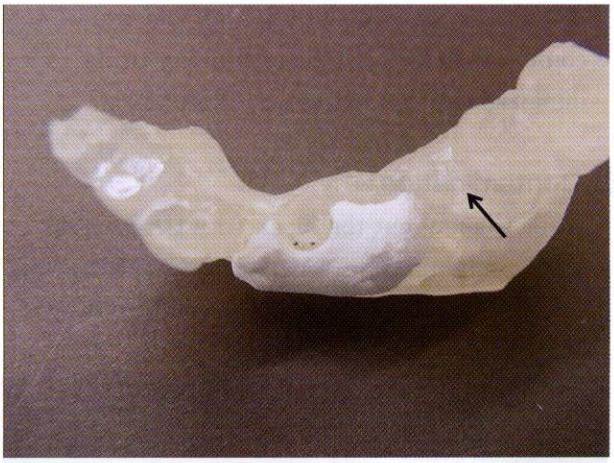

Fig. 11: (2) Adaptability from above.

4) Contamination examination of WC bar by EDX As seen in Fig 12 the tungsten was not detected.

4. Discussion

3DX Multi image micro CT (FPD8) manufactured by Morita co. used in this study has a flat panel detector (FPD) which converts x-ray map into digital signal. It has improved image quality and reduced the quantity of radiation. FPD is not affected by the magnetic field, is highly sensitive with higher resolution, wide dynamic range and excellent gradation expression and provides high quality 3D

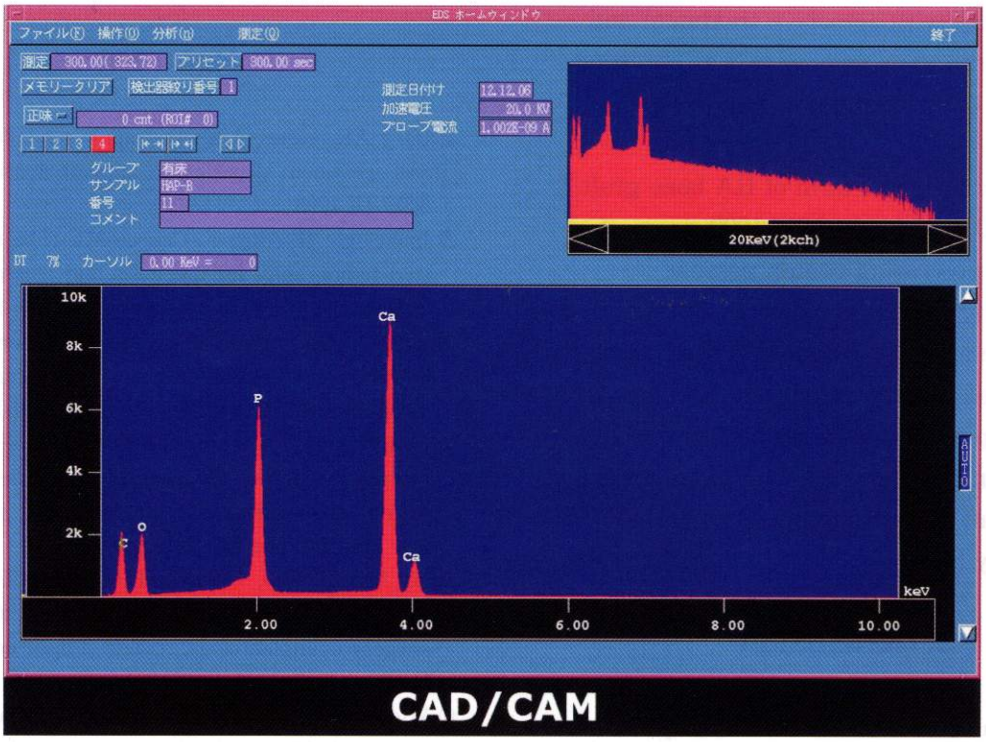

Fig. 12: EDX analysis of the HA bone graft to ascertain the contamination of tungsten (W) caused by shaving process.

photographic image with less distortion. It has high resolution of more than 2.0LP/mm (MTF10%) and voxel size 0.08mm (cube). This high resolution CT was chosen to minimize the radiographic area of the bone defect region and obtain higher accuracy [13-15].

There are many simulation software for clinical implant treatments [16,17], but software that can simulate the bone augmentation volume are very limited. SimPlant was used in this study and bone augmentation simulation has maximized the advantage of SimPlant.

Avoiding the contact of the implant and HA bone graft block will reduce the external force such as occlusal load on HA bone graft block and leads to remodeling of autologous bone around the implant. This is important for a good prognosis of the implant in a long term. Clinical use of guided surgery for bone augmentation simulation and implant placement should be considered.

In order to precisely reproduce the bone augmentation image, GM-1000, the processing machine at CG processing center [11,12] was selected. HA bone graft block exactly matched the resin bone defect model made by 3DP for the preliminary experiment. Therefore this ultra precise processing machine GM-1000 is considered to be the world's top Japanese technology with submicron level control mechanism, linear motor driver system, 5 spindle machining control, 24 hour consecutive material auto changing system and strong structure for higher processing accuracy.

HA block used in this study was HOYA Technosurgical Co. apaceram-U5. [18,19] When porosity of the apaceram is 50%, 3 point bending strength is 16MPa, compressive strength is 30MPa. This product is made of high purity synthetic HA and is a bone substitute of the same quality to biological apatite which is the basic component of the bone tissue. It has high biological compatibility and encourages the bone tissue formation and binds directly with newly formed bone [20,21].

After sterilizing the bone graft block shaped out of CAD/CAM with autoclave treatment and gamma ray sterilization, no change was observed in its structure of strength according to HOYA Technosurgical Co.

When reproducing the form of HA bone graft block with CAD/CAM using GM-1000: processing machine at GC processing center, possible contamination by the bar could occur during shaping out the apatite block. In this study both apatite block before shaping out and HA bone graft block after shaping out were verified with EDX and no tungsten was detected. Therefore possibility of HA bone graft block contamination can be considered very low.

5. Conclusion

For bone augmentation, block bone transplant using autologous bone or GBR method using granular bone substitute and multiple membrane are commonly used, but it is difficult to recreate the ideal form because of the difficulties involved in prediction of absorbed amount of the grafting material over time and difficulty of the surgery itself.

Bone graft blocks reproduced from CT simulation in this study proved that simulation software can design an ideal bone augmentation form and precisely reproduce it with CAD/CAM technology and apatite form itself has long term retentivity and stability and it also reduces operation time. Therefore it strongly suggests its usability compared to other existing bone augmentation methods.

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