Longitudinal Evaluation of Autogenous Bone Graft Prior to Implant Placement

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Purpose: To conduct a longitudinal evaluation of sites grafted with autogenous bone prior to implant placement using a dental cast with a 3D modeling system. ***Materials and Methods:*** A total of nine patients underwent implant treatment with bone grafting for anterior missing teeth. Informed consent was obtained from each patient. Casts were made and evaluated at three time periods, including before bone grafting (Pre BG), 4 or 5 months after grafting (Post BG), and 4 or 5 months after implant placement (Post IP). 3D data of these casts were acquired using a 3D digital scanner and then superimposed with reference to the remaining teeth. The volume of the anterior area of the cast was evaluated Pre BG and Post BG. ***Results:*** Accuracy of superimposition on the remaining teeth was between 20 and 50 µm. Horizontal differences Post BG and Post IP were 0.1 to 1.6 mm. The volume Post IP decreased by 14% to 38% compared to the volume Post BG. ***Conclusions:*** This 3D modeling technique allowed 3D evaluation before and after bone grafting. Results suggested that the volume of the maxilla was sequentially decreased after bone grafting. *Int J Oral Maxillofac Implants 2024;39:845–850. doi: 10.11607/jomi.10855*

Keywords: bone graft, bone loss, 3D digital evaluation

Implant placement that successfully retains function, esthetics, and long-term sustainability requires the availability of sufficient bone and gingival tissue.[1–3] However, bone height at the implant site is sometimes compromised. In these cases, bone must be managed by ridge augmentation or bone regeneration.[4] In cases with insufficient bone height or width, bone augmentation has been conducted using autografts, allografts, xenografts, or artificial bone. In particular, the safety and efficacy of autografts has been noted[5–7] due to their biologic superiority in terms of osteoconductivity and biocompatibility.[8] However, disadvantages of this procedure include possible postoperative sensory disturbances, discomfort at the donor site, and increased operative time.[1] Moreover, managing the timing of implant placement is hampered by the possibility of bone resorption.

Changes in bone volume using linear measurements of dental casts or CT scan data have been reported.[9,10] To date, 3D resorption of grafted bone has not been reported primarily because of difficulties in 3D evaluation and radiographic artifact. In contrast, no-contact 3D scanners and software enable the analysis of dental casts in three dimensions and the evaluation of clinical treatment efficacy and prognosis.[11–13]

The aim of this study was to establish a method to evaluate 3D changes in bone volume and bone resorption over time using dental casts and a 3D scanner

MATERIALS AND METHODS

A total of nine patients were enrolled and underwent implant treatment including bone augmentation with autogenous bone at the implant clinic of Dental hospital, Aichi Gakuin University. The participants of this study were relatively healthy (ASA-1 and ASA-2) and had no significant systemic conditions. Informed consent was obtained from each patient. Patients with uncontrolled diabetes, compromised immunity, or active periodontitis were excluded. This project was approved by the ethics committee of our institution (No. 261).

Autogenous bone was obtained from the mandibular ramus in all patients. The case summary of each patient is shown in Table 1. For case number eight, the patient had two implant sites because implant placement was performed on both sides. All patients in this study had undergone tooth extraction at least 6 months before bone grafting. Indications for bone grafting were evaluated based on careful clinical examination with oral inspection and radiologic examination using CT imaging to observe the approximate cortical volume in each patient.

We used a standardized two-stage surgical protocol. The surgical procedures were performed under local

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Table 1 Patient Characteristics

Case no.	Age, sex	Missing teeth	Autogenous bone site	Implant area
1	36, F	1|	Ramus	2|
2	33, F	2|	Ramus	1|
3	55, F	21|123	Ramus	21|123
4	25, F	21|123	Ramus	21|123
5	29, F	21|12	Ramus	1|1
6	23, M	1|	Ramus	1|
7	34, M	|1	Ramus	|1
8	20. F	43|2	Ramus	43|2
9	39, F	|3	Ramus	|3

anesthesia. The proposed recipient site for the graft was exposed prior to graft harvest in all cases. A mucoperiosteal flap was elevated by a crestal incision and vertical releasing incisions on the mesial and distal aspects. The alveolar ridge was then clinically examined.

An incision was made medial to the external oblique ridge, and the mucoperiosteal flap was elevated, exposing the lateral aspect of the ramus. Then a 1.5 × 1.5 × 0.5 cm bone graft was prepared using a Lindemann bur. The bone was trimmed and fixed with 1.5-mm titanium osteosynthesis screws. In addition, bone chips that were harvested using a bone scraper at the donor site were packed around the bone block to fill gaps between the block graft and the recipient bone. The entire graft was covered by a collagen membrane (Terudermis, GC Japan) and closed with 4/0 resorbable sutures.

After a healing period of 4 to 5 months, clinical and radiographic evaluations were performed. A crestal incision and subperiosteal dissection of the alveolar crest was performed, and the fixation screws were removed. Implant site preparation and implant placement were performed using laboratory-manufactured surgical guides.

Impressions used to make the cast were taken at three time periods, including before bone grafting (Pre BG), 4 or 5 months after bone grafting (Post BG), and 4 or 5 months after implant placement (Post IP). A ready-made tray and an alginate impression material (Hi-Technicol, GC Japan) were used to make the impressions. The alginate impression material was mixed in the same way each time according to the manufacturer's indicated mixing ratio with room temperature water. The dental casts were made using dental stone (GC New Plastone II, MSLI Dental). The dental stone was mixed with the same water/powder ratio in a vacuum mixing machine and poured into the alginate on the vibration device.

Data of dental casts were acquired using a 3D data acquisition system (Rexcan III, Solutionix). Rexcan III is an industrial 3D scanner that uses phase-shifting optical triangulation and CCD twin-camera technology. This system enables rapid acquisition of 3D data (within 2 seconds) and claims excellent accuracy (± 0.001 mm). The scan was performed by placing a marker that was 3 mm in diameter on the palatal area or lateral surface of the dental cast and then firmly affixing the cast to the measurement board. Multiangle scanning was performed until the whole surface of the dental cast was acquired, including the undercut of the dental arch and interdental spaces. The acquired multiscanned data was aligned with reference to the marker and integrated using another software (eZscan, Solutionix). The integrated data were converted to the STL format and imported into a 3D editing software (Geomagic Studio, Geomagic; Fig 1).

Data from three time points (Pre BG, Post BG, and Post IP) were superimposed based on all the teeth that were not involved in the implant treatment (Fig 2). The surface of the teeth was selected and superimposed using the "Best Fit" function. This function randomly extracts and aligns 300 points to make the datasets as close to each other as possible, then randomly extracts and aligns 1,500 points. For the present study, superimposition error was defined as the average error of 1,500 points after superimposition.

Volume change of the grafted area was calculated using a 3D analysis software (Geomagic Qualify, Geomagic) as linear change and 3D change. For the linear change, the differences between Pre BG and Post BG and between Pre BG and Post IP were measured using the software on the axial plane parallel to the occlusal plane, which included the point of greatest protrusion in the bone-grafted area (Fig 3). For the 3D change, a Boolean operation was made to calculate the differences between Pre BG and Post BG and between Pre BG and Post IP, and the volume of the difference was calculated thereafter (Fig 4). The linear and 3D changes were statistically evaluated by the paired *t*-test ($P = .01$).

RESULTS

The superimposition error of all remaining teeth (not including the implant) was 0.02 to 0.05 mm (Fig 5). The linear change from Pre BG to Post BG (2.63 ± 1.05 mm) was significantly larger than the linear change from Pre BG to Post IP (1.70 ± 0.93 mm; t [9] = 5.72; $P = .001$; Fig 6). The mean linear change between Post BG and Post IP was 0.92 ± 0.51 mm. The 3D change from Pre BG to Post BG was significantly larger than the 3D change from Pre BG to Post IP (167.62 ± 103.43mm^3; t [9] =3.97;

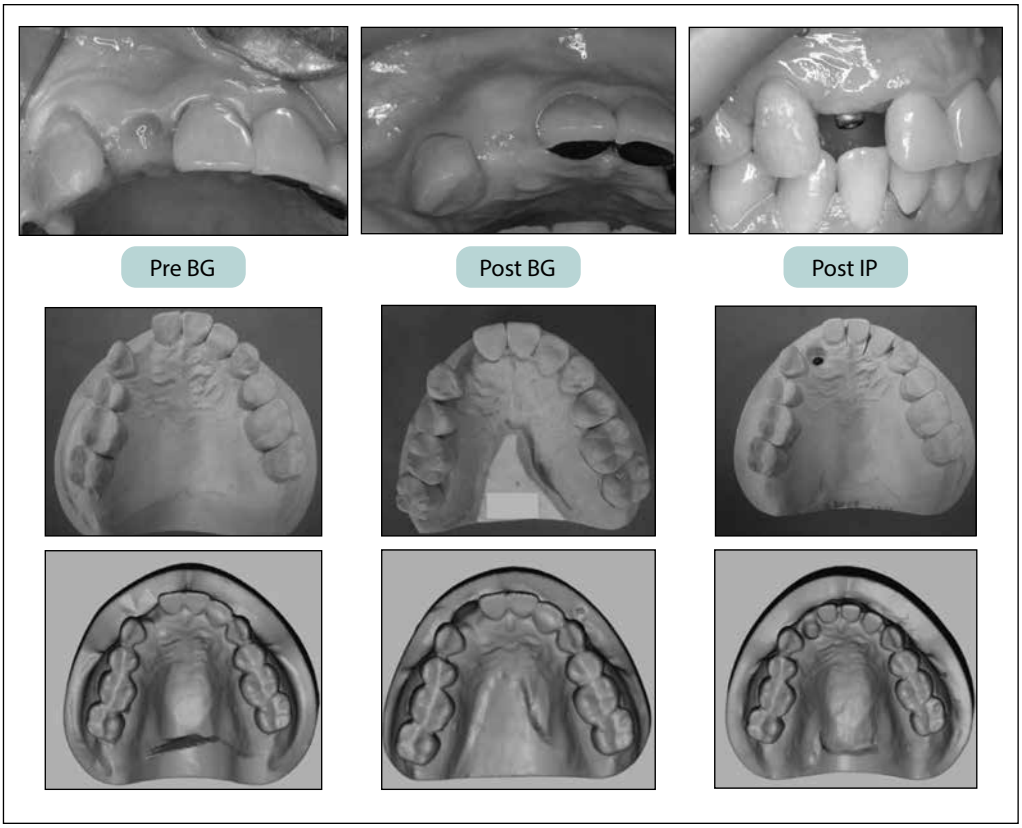

Fig 1 Intraoral photo, dental cast, and 3D data at Pre BG, Post BG, and Post IP (representative case 2).

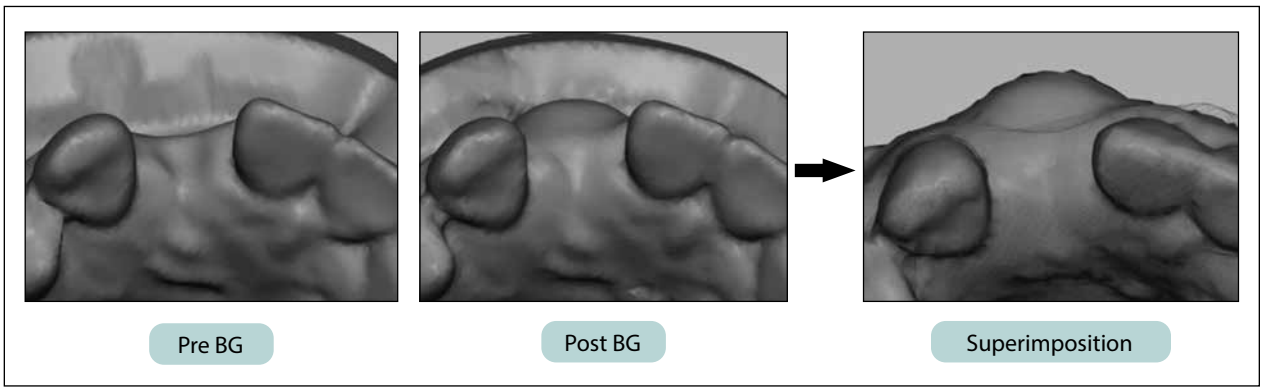

Fig 2 Superimposition of data from Pre BG and Post BG.

P = .0014; Fig 7). The mean volume change between Pre BG to Post BG and Pre BG to Post IP was 26.7% ± 8.11%.

DISCUSSION

In this study, changes in bone volume were evaluated in 2D and 3D using dental casts and a 3D scanner during implant treatment. 2D evaluation showed a significant decrease between Pre BG to Post BG and Pre BG to Post IP. 3D evaluation showed a significant decrease in bone volume between Pre BG to Post BG and Pre BG to Post IP. These results show that bone volume decreased after implant placement.

Use of bone augmentation prior to implant placement has increased, particularly in the esthetic zone. While predicting the required volume of grafted bone can be difficult, it must be sufficient to ensure implant stability in the long term. Bone resorption has been evaluated quantitatively,[9–10] and radiographic evaluation using CT data cannot avoid the side effect of irradiation. Though Mayfield et al[9] reported a clinical and radiographic evaluation of implant sites using dental measurements, 3D evaluation proved difficult.

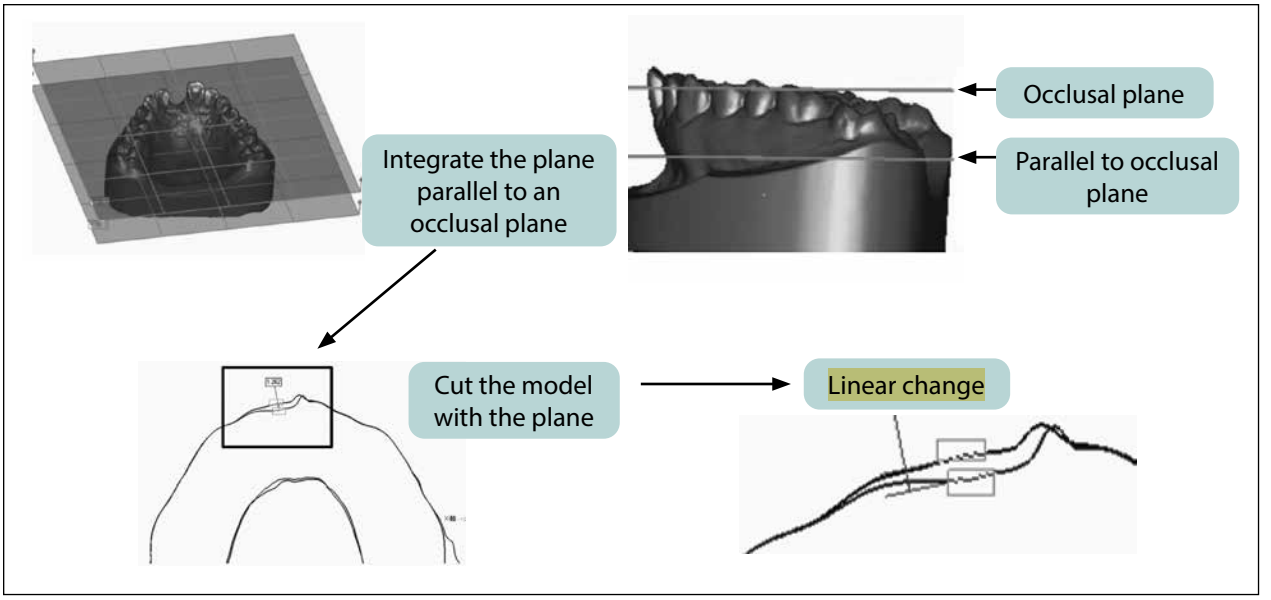

Fig 3 Schema for examination of linear change (representative case 2).

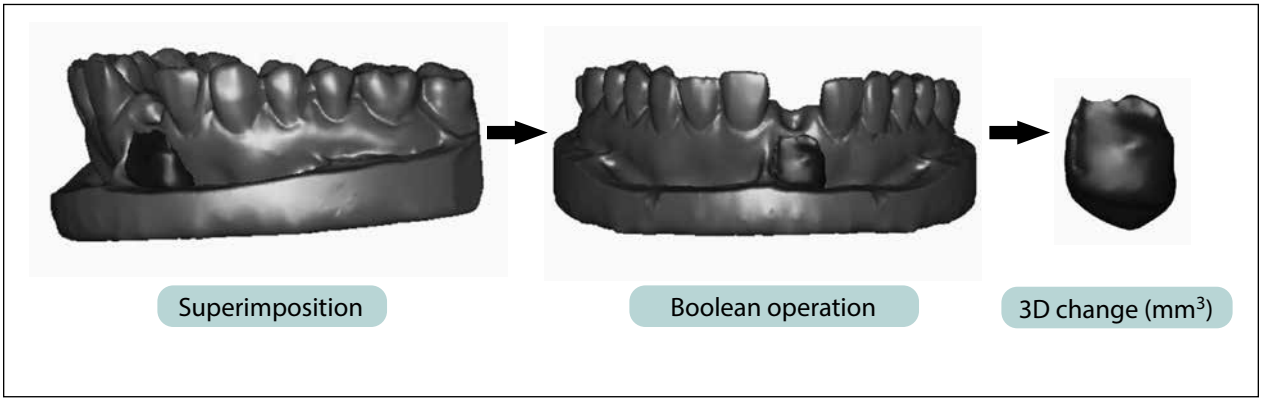

Fig 4 Examination of 3D change (representative case 2).

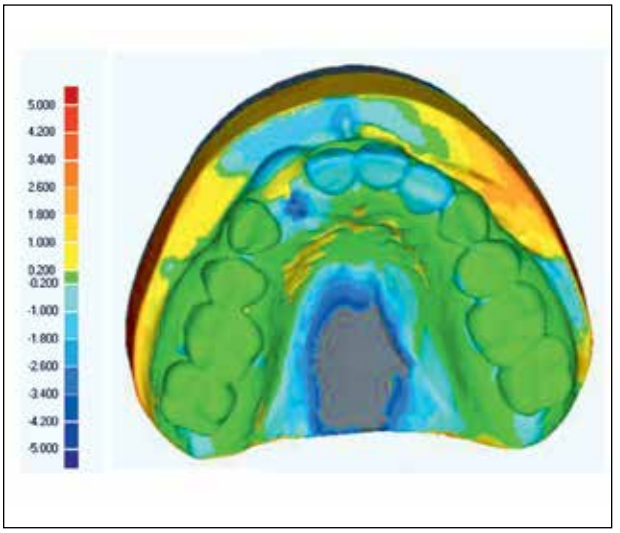

Fig 5 Color mapping of superimposition data from Pre BG and Post BG (representative case 2).

On the other hand, 3D analysis of dental casts has been applied to prognosis for malocclusion or accuracy of the cast.[11,12] Sabouchi et al[14] evaluated the 3D accuracy of dental casts made from several types of impression systems using 3D data acquisition. In their study, bone resorption before and after guided bone regeneration (GBR) was successfully evaluated on dental casts using a 3D scanner without further invasive procedures.

The superimposition error in the present study was 0.02 to 0.05 mm, which included a purported scanner error of 0.001 mm. Considering the distortion of impression material and expansion of dental stone,[15,16] the measurement accuracy in this study appears acceptable.

Simion et al[1] reported that healing after bone grafting takes 4 to 5 months and that the horizontal volume of bone shrinks by 39% to 76% over that time period. In the present study, the evaluation of volume change before and after GBR and after implant placement

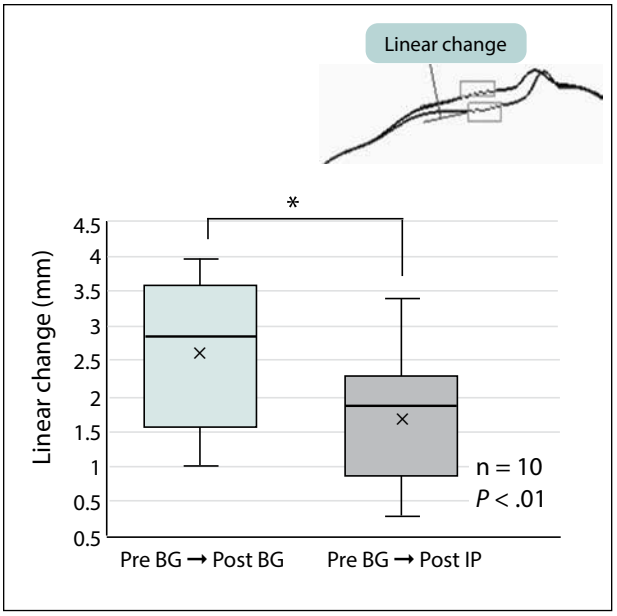

Fig 6 Linear differences between Pre BG and Post BG and between Pre BG and Post IP.

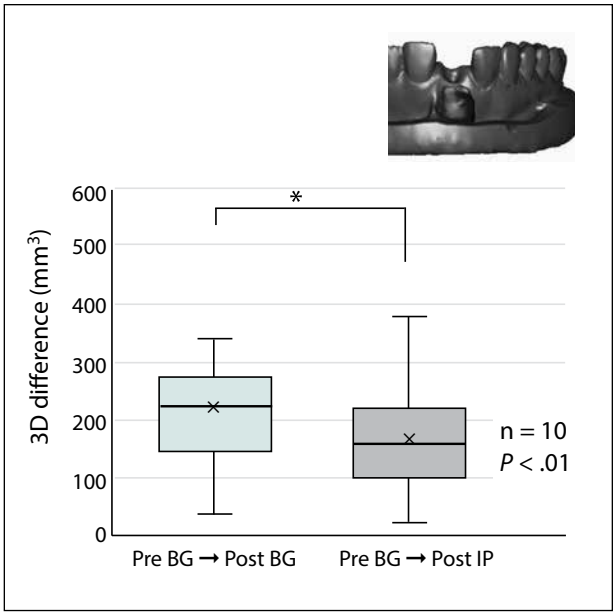

Fig 7 3D differences between Pre BG and Post BG and between Pre BG and Post IP.

suggested that the horizontal volume increased after bone grafting due to the grafted bone. Compared to Pre BG, an increase of 1.70 ± 0.93 mm was seen horizontally Post IP, whereas an increase of 2.63 ± 1.05 mm was seen horizontally Post BG. The 3D volume change observed Post IP compared to Pre BG was 20% to 30% less than that observed between Pre BG and Post BG. This indicates that bone resorption continues not only during the healing period but also afterward to a small extent. However, a better understanding of bone resorption after implant placement requires additional study with longer-term follow-up.

Several limitations of our study are worth noting. The first involved the requirement for a dental cast. In this short-term observation, we evaluated bone volume by utilizing dental casts made to fabricate prostheses. For a long-term observation, the use of an oral scanner may be better than impressions of dental casts because it would allow the evaluation of more subjects as well as the evaluation of the posterior region or mandible. Second, we were unable to conduct soft tissue evaluation. Our methodology could not be used to evaluate bone resorption in cases with connective tissue grafting or placement of grafted material because the volumetric change in these cases included both soft and hard tissue configuration. The combination of 3D data in this study with CT data allowed for confirmation of the relationship between soft tissue and bone at the implant site. While this is helpful in estimating bone resorption and in planning surgery or prognosis, the side effect of excessive radiation from multiple CT scans to evaluate bone volume by CBCT cannot be ignored. In this study, GBR was performed with a standardized technique. Our methodology enables the evaluation bone resorption for other surgical techniques in future studies.

CONCLUSIONS

3D evaluation was achieved via 3D scanning and superimposition using dental modeling software before GBR, after GBR, and after implant placement. The results suggest that bone volume decreased after implant placement.

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REFERENCES

1. Simion M, Jovanovic SA, Trisi P, Scarano A, Piattelli, A. Vertical ridge augmentation around dental implants using a membrane technique and autogenous bone or allografts in humans. Int J Periodontics Restorative Dent 1998;18:8–23.
2. Kan JYK, Rungcharassaeng K, Kim J, Lozada JL. Goodacre CJ. Factors affecting the survival of implants placed in grafted maxillary sinuses: A clinical report. J Prosthet Dent 2002;87:485–489.
3. Aghaloo TL, Moy PK. Which hard tissue augmentation techniques are the most successful in furnishing bony support for implant placement? Int J Oral Maxillofac Implants 2007;2(suppl):s49–s70.

4. Masaki C, Nakamoto T, Mukaibo T, Kondo Y, Hosokawa R. Strategies for alveolar ridge reconstruction and preservation for implant therapy. J Prosthodont Res 2015;59:220–228.
5. Sbordone L, Toti P, Menchini-Fabris GB, Sbordone C, Piombino P, Guidetti F. Volume changes of autogeneous bone grafts after alveolar ridge augmentation of atrophic maxillae and mandibles Int J Oral Maxillofac Implants 2009;38:1059–1106.
6. Smolka W, Eggensperger N, Carollo V, Ozdoba C, Iizuka T. Changes in the volume and density of calvarial split bone grafts after alveolar ridge augmentation. Clin Oral Implants Res 2006;17:149–155.
7. Widmark G, Andersson B, Ivanoff CJ. Mandibular bone resorption in the anterior maxilla for single-tooth implants. Int J Oral Maxillofac Implants 1997;26:106–109.
8. Nkenke E, Stelzle F. Clinical outcomes of sinus floor augmentation for implant placement using autogenous bone or bone substitutes: A systematic review. Clin Oral Implants Res 2009;20:124–133.
9. Mayfield L, Skoglund A, Nobréus N, Attström R. Clinical and radiographic evaluation, following delivery of fixed reconstructions, at GBR treated titanium fixtures. Clin Oral Implants Res 1998;9:292–302.
10. Simon BI, Von Hagen S, Deasy MJ, Faldu M, Resnansky D. Changes in alveolar bone height and width following ridge augmentation using bone graft and membranes. J Periodontol 2000;71:1774–1791.
11. Ozawa S, Yoshioka F, Tanaka Y. Analysis of study casts on occlusal treatment using 3D digitizer [in Japanese]. J Japanese Acad Occlusion Health 2011;17:4–9.
12. Mazzocco F, Lops D, Gobbato L, Lolato A, Romeo E, del Fabbro M. Three-dimensional volume change of grafted bone in the maxillary sinus. Int J Oral Maxillofac Implants 2014;29:178–184.
13. Del Fabbro M, Rosano G, Taschieri S. Implant survival rates after maxillary sinus augmentation. Eur J Oral Sci 2008;116:497–506.
14. Sabouchi M, Bajoghli F, Abolhasani M. Evaluation of the three-dimensional accuracy of implant impression techniques in two simulated clinical conditions by optical scanning. Int J Oral Maxillofac Implants 2015;30:26–34.
15. Ceyhan JA, Johnson GH, Lepe X. The effect of tray selection, viscosity of impression material, and sequence of pour on the accuracy of dies made from dual-arch impressions. J Prosthet Dent 2003;90:143–149.
16. Ceyhan JA, Johnson GH, Lepe X, Phillips KM. A clinical study comparing the three-dimensional accuracy of a working die generated from two dual-arch trays and a complete-arch custom tray. J Prosthet Dent 2003;90:228–234.