# New Technologies in Oral Science[*1]

JMAJ 54(3): 194–196, 2011

Tsuyoshi TAKATO[*2]

## Introduction

Looking back on the development of oral science and dentistry, dentistry has often seen its greatest developments through fusion with neighboring sciences, such as engineering and pharmaceutics. These interdisciplinary efforts have led to dental innovations such as electronic root canal length measurement devices, adhesive resin, dental implants, computer-aided design/computer-aided manufacturing (CAD/CAM) for the production of dental prosthetics, and cone beam dental computed tomography (CT). I would particularly like to note that electronic root canal length measurement devices and adhesive resin were developed in Japan. With the rapid development of science and technology in recent years, it seems certain that this trend will continue. In this manuscript, I will introduce important new technologies in oral science.

## Augmented Reality System

First, we can anticipate the introduction of robotic surgical systems in dentistry, especially in oral and maxillofacial surgery. Today, the results of surgical operations are mainly dependent on the experience, technique, and inborn ability of the individual surgeon. To overcome this limitation, it would be useful to introduce an augmented reality (AR) system that could provide surgeons with visual information about invisible regions in the operative field. AR is analogous with virtual reality (VR) in many ways. It is a combination of virtual and graphic three-dimensional images transmitted to a user. However, AR is different from VR in that it involves overlaying graphic images onto real life, engaging the user in a semi-immersive, interactive, three-dimensional environment. By superimposing virtual images onto real life, an experience can be heightened or modified.

One of the main uses of AR in oral-maxillofacial surgery is in visualizing deep structures, thus allowing minimally invasive operations. For example, in orthognathic surgery, points of incision on the mandibular bones could be preoperatively marked on an augmented image and then adjusted or modified before being overlaid on the real patient, allowing the surgical procedures to be clearly mapped.[1] AR allows surgeons to maintain a fixed field of vision on the surgical site while graphic guides are projected onto the site as a reference.

Such assisted surgical techniques can be applied to not only orthognathic surgery or dental implant surgery but also dental root canal treatment, where the operative field is invisible. For this reason, the introduction of an AR system is likely to change clinical dental technology dramatically. We are currently developing an AR system in collaboration with the Department of Technology at the University of Tokyo (**Fig. 1**).

## Regenerative Medicine Approach

Next I would like to mention regenerative medicine and tissue engineering in the field of oral science and dentistry. Because dentistry deals primarily with teeth, which have little self-healing ability, its general categorization as a materials science has often been emphasized.

*1 Part of this manuscript appeared in the proceedings of the International Symposium on Oral Medicine 'Grand Design for Future Dentistry' that was held on December 4, 2010 at Acros Fukuoka International Conference Hall (Fukuoka, Japan).

*2 President, Japanese Stomatological Society. Department of Oral-Maxillofacial Surgery, Graduate School of Medicine, The University of Tokyo, Tokyo, Japan (takato-ora@h.u-tokyo.ac.jp).

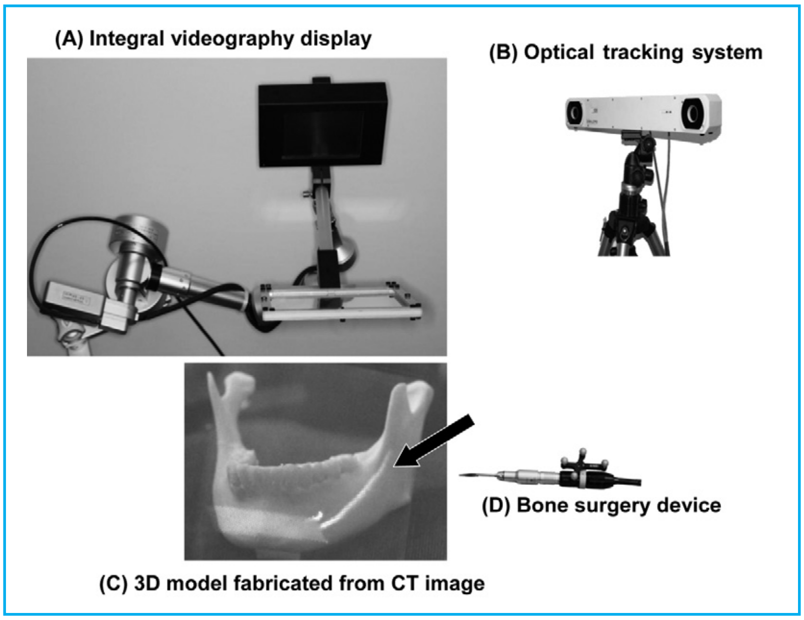


**Fig. 1 An AR system under development at the university of Tokyo**

Augmented reality images result from the superimposition of the virtual onto the real anatomy of the patient. Note that a three-dimensional (3D) model fabricated from a computed tomography (CT) image was used as a substitute for the real anatomy of the patient in Fig. 1. The major components of this system are (A) an integral videography display, (B) an optical tracking system and (D) a surgery device with markers to track the movement. AR allows visualization of the canalis mandibulae (arrow) by superimposing the virtual anatomy and 3D model (C).

In recent years, however, conservative dental pulp therapy with antibiotics and bone regenerative therapies such as the guided tissue regeneration (GTR) method have attracted a great deal of public attention. The emergence of such treatments has made the biological aspects of dentistry more and more important. Almost all dental and oral diseases—including dental caries, teeth or periodontal tissue loss due to periodontal disease, bone defects or hypoplasia of cartilage associated with cleft palate, bone and cartilage defects, and oral soft tissue caused by tumors or trauma—could be candidates for a regenerative medicine approach. The introduction of regenerative medicine and tissue engineering may therefore cause a paradigm shift in oral science and dentistry.

The Division of Tissue Engineering was established at the University of Tokyo Hospital in 2001 with the aim of pursuing regenerative medicine research. Within this division, our group has conducted research on regenerative medicine, such as 3D structured artificial bones, vascular regenerative medicine using gelatin-basic fibroblast growth factor (FGF), corneal reconstruction using an autologous cell sheet of amnion, and cartilage regeneration using human chondrocytes. Here, as an example of the development of tissue engineering for the oral and maxillofacial regions, I will now present the 3D structured artificial bones and cartilage regenerated using human chondrocytes that our group has been developing in recent years.

## Artificial bones

First, I would like to present some custom-made artificial bones, or CT-Bones, as an important development in the field of bone-tissue engineering. We fabricated novel custom-made artificial bones from $\alpha$-calcium triphosphate (TCP) powder using an inkjet printer. From March 2006 to July 2009, 20 patients who had non-weight-bearing maxillofacial deformities due to congenital anomalies, trauma, or tumor resection were enrolled to receive mandibular or maxillary reconstruction at our institution. This study was approved by the Ethical Committee of the Faculty of Medicine at the University of Tokyo.

The CT-bones had dimensional compatibility in all patients. The operation time was reduced due to the minimal need for size adjustment and fixing manipulation. The postsurgical computed tomography analysis detected partial union between the artificial bones and host bone tissues. There were no serious adverse reactions. These findings provide support for further clinical studies of inkjet-printed custom-made artificial bones.[2]

## Tissue-engineered cartilage

I will next describe the implant-type tissue-engineered cartilage we are developing for nasal augmentation of cleft lip nasal deformities. The nasal deformity in Cleft Lip and Palate (CLP) has conventionally been treated with autologous bone grafts or silicone implants. However, certain problems, including a lack of elasticity and subsequent deformity and dislocation, have been pointed out. Incidentally, cartilage tissue engineering has already been applied in repairing focal joint defects and revising cosmetic silicone implants. It is expected that this method can also be applied in the nasal augmentation of CLP.

However, there are several problems with the present cartilage tissue-engineering techniques. For example, the methods are performed using a cell suspension or cell/gel mixture and the volume is extremely limited. In addition, while isolated chondrocytes are proliferated in monolayer, the matrix synthesis of chondrocytes is drastically decreased. The matrix synthesis in chondrocytes remains decreased even after cultured chondrocytes are injected into the focal joint defects.

In contrast, our novel methods induce rapid proliferation without FBS[3] and fabricate 3D-structured tissues. Moreover, maturation of tissue-engineered cartilage is enhanced in the 3D culture with BMP-2, insulin, and thyroid hormone[4]. With these technologies, we have succeeded in making an implant-type tissue-engineered cartilage with a 3D shape and sufficient hardness.

## Tooth regeneration

Finally, I would like to mention tooth regeneration. It has been reported that tooth regeneration has been successfully achieved in an animal model.[5] However, in terms of clinical use, there are many problems to be overcome, such as the organization of the complex structure of teeth and various safety concerns. Nevertheless, since tooth regeneration is a highly desirable goal, I hope investigations in this field will continue to advance and that clinical applications will one day be realized.

## References


1. Shuhaiber JH. Augmented reality in surgery. Arch Surg. 2004; 139(2):170–174.
2. Saijo H, Igawa K, Kanno Y, et al. Maxillofacial reconstruction using custom-made artificial bones fabricated by inkjet printing technology. J Artif Organs. 2009;12(3):200–205.
3. Takahashi T, Ogasawara T, Kishimoto J, et al. Synergistic effects of FGF-2 with insulin or IGF-I on the proliferation of human auricular chondrocytes. Cell Transplant. 2005;14(9): 683–693.
4. Liu G, Kawaguchi H, Ogasawara T, et al. Optimal combination of soluble factors for tissue engineering of permanent cartilage from cultured human chondrocytes. J Biol Chem. 2007;282(28): 20407–20415.
5. Ikeda E, Morita R, Nakao K, et al. Fully functional bioengineered tooth replacement as an organ replacement therapy. Proc Natl Acad Sci U S A. 2009;106(32):13475–13480.