

Dental PACS development in Korea

Eun-Kyung Kim

Department of Oral and Maxillofacial Radiology, School of Dentistry, Dankook University

ABSTRACT

Picture archiving and communication system (PACS) is an image information technology system for the transmission and storage of medical images. In Korea the first full PACS was installed at Samsung Medical Center in 1994, but, the rate of distribution was very slow. The government's approval for the medical insurance reimbursement for full PACS examinations in November 1999 became the turning point. Thereafter the number of hospitals with full PACS has steeply increased. In September of this year, PACS was installed at 906 medical institutes, including most of university hospitals and general hospitals. The first full dental PACS was installed at Wonkwang University Dental Hospital in 2002. Now ten out of eleven university dental hospitals implemented full dental PACS. The current status and technological factors of dental PACS in Korean university dental hospitals and the future perspectives of dental PACS are described. (*Korean J Oral Maxillofac Radiol* 2008; 38 : 189-94)

KEY WORDS : PACS; Dental PACS; Information Technology; DICOM

Introduction

Picture archiving and communication system (PACS) is an image information technology system for the transmission and storage of medical images. The hospitals with full PACS become to be filmless. PACS is comprised of four elements. They are image acquisition system such as computed radiography (CR), digital radiography (DR), computed tomography (CT), magnetic resonance imaging (MRI), DICOM gateway and so on, database and storage system, distribution network system and image display and output system. The benefits of PACS are manifold. First is saving of cost such as film and chemical cost, personal cost, film storage and handling cost, etc. Second is decreased environmental pollution with no use of chemicals and films. Third is customer satisfaction, for example, improved image quality, decrease of film loss, time saving from exposure to report, improved rate of interpretation, easier preparation of teaching image files, etc.¹ However, to implement PACS, some barriers need to be overcome. These arise from early on in the project, when the implementation is planned, until routine use of PACS has been established. According to Pare and Trudel,² four distinct groups of barriers

can be distinguished throughout the implementation process. These are economic barriers, technical barriers, organizational barriers and human barriers.

In spite of the convenience and benefits of PACS, the cost of installing PACS is high. Most Korean hospitals could not afford to purchase this system easily until the reimbursement of the cost of PACS by National Health Insurance was decided. After the Korean government started to reimburse the cost of PACS, the number of hospitals installing PACS was rapidly increased. At present (November 1st, 2008), ten out of eleven dental university hospitals installed full PACS.

The history, the current status and technological factors of dental PACS in Korean university dental hospitals and the future perspectives of dental PACS are described.

History of Dental PACS

The concept of PACS was first introduced by Prof. Lemke in 1979. And the first clinical PACS project was performed at Washington University and Georgetown University by the US Army in 1985. But it was failed because of immature technology and lack of understanding about clinical requirements. New PACS project, Medical Diagnostic Imaging Support system (MDIS), was attempted and installed successfully at Madigan Army Medical Center in 1992.³ This was the first filmless hospital, and this MDIS PACS model was installed at Baltimore VA medical center, Samsung Medical center in Seoul

*The present research was conducted by the research fund of Dankook University in 2008.

Received November 10, 2008; Accepted November 20, 2008

Correspondence to : Prof. Eun-Kyung Kim

Department of Oral and Maxillofacial Radiology, School of Dentistry, Dankook University, San 7-1, Sinbu-dong, Cheonan, Chungnam 330-716, Korea
Tel) 82-41-550-1922, Fax) 82-41-556-7127, E-mail) ekkim@dku.edu

and Hammersmith Hospital in London.³ Since late 1990s, next generations of PACS have been successfully installed at many hospitals all around the world. With the technical progress of networks, computers, storages and monitors, success rate of PACS was increased.

In case of dental PACS, Dove et al.⁴ reported “design and implementation of an image management and communication system for dentomaxillofacial radiology” in 1992. They pointed out that, in order to enhance the development of IMACS in dentistry, two major issues needed to be addressed. First, standards for hardware and software, second, legal acceptance of radiographic images in digital format should be established. In 1998, Chen et al.⁵ reported implementation of total OMFR IMACS at school of Dentistry, National Taiwan University. They mentioned the differences between dental PACS and medical PACS. There were larger number of examinations, smaller average image size and higher resolution images required in dental PACS. Their system was used parallel to the conventional film-library system. In November 2000, ADA adopted DICOM as standard for communication of digital dental images.⁶ In 2001, Okamura et al.⁷ reported integration of PACS at Kyushu University Dental Hospital with RIS and HIS. HIS is a system to support patient care by managing pt information as well as staff notes. RIS is a system to cover the

data generated by the Radiology department, such as radiology reports and record of examinations. Their PACS was DICOM-based system and did not involve intraoral radiography. In 2003, Gotfredsen and Wenzel⁸ described a flexible PACS to handle and communicate digital image data from various radiography systems. It was the self-developed PACS providing its own image data format, no DICOM-based. In 2005, Park et al.⁹ reported implementation of DICOM-based dental full PACS at Yonsei University dental hospital in Korea. And they pointed out the successful implementation of PACS was important because it was the first step to keep a close connection with HIS including EMR, OCS and ERP. In 2007, Iwasaki et al.¹⁰ reported DICOM-based dental full PACS at Tokushima University Medical and Dental Hospital with development of a hanging protocol for displaying digital dental images. In 2008, Nair et al.¹¹ described enterprise-wide implementation of digital radiography at university of Florida dental healthcare system. They mentioned that the unique challenges to implementation of PACS in dentistry were as follows: use of high resolution small area sensors, unique hanging protocols, task-specific post-processing of images, use of CBCT in dentistry, inability to bridge to specialty-specific software, digital images taken by students needed to be evaluated by faculty before approval, and need to integrate seamlessly with medical system.

Table 1. Number and percentage of PACS installation in Korea (by Health Insurance Review and Assessment Service¹³)

Year		Tertiary Hospital	General Hospital	Hospital	Clinic	Dental Hospital	Dental Clinic	Sum
2008.9.30	No. of medical institutes	43	268	1,834	26,482	163	13,664	42,454
	No. of unit of PACS	55	265	377	184	14	11	906
	% of PACS installation	127.91	98.88	20.56	0.69	8.59	0.08	2.13
2004.9.30	No. of medical institutes	42	241	941	24,196	110	11,970	37,500
	No. of unit of PACS	37	144	116	11	3	0	311
	% of PACS installation	88.10	59.75	12.33	0.05	2.73	0.00	0.83

Table 2. General information of 10 dental PACS in Korean dental university hospitals

No. of institution	Operation since	PACS vendor (at beginning)	PACS vendor (now)	No. of unit chairs	No. of workstation
1	2002.11	MEDICOTECH	INFINITT	60	55
2	2003.01	MAROTECH	INFINITT	280	200
3	2004.02	INFINITT	INFINITT	263	262
4	2004.02	MAROTECH	INFINITT	102	63
5	2004.09	INFINITT	INFINITT	143	160
6	2005.01	INFINITT	INFINITT	157	300
7	2005.01	INFINITT	INFINITT	129	174
8	2006.01	MAROTECH	INFINITT	98	61
9	2007.07	Medical standard	Medical standard	110	111
10	2008.11	INFINITT	INFINITT	156	216

History and Current Status of Dental PACS in Dental University Hospitals in Korea

In Korea, the first large-scale PACS was installed at Samsung medical Center in 1994.

Since that successful installation, great diffusion of partial and mini-PACS were occurred, but not full PACS. At the end of year 1997, there was serious economic crisis in Korea. We

had to import every single film from abroad because there is no Korean company to produce X-ray films. Due to shortage of US dollar and rise of exchange rate, imported film cost was rapidly increased. In November 1999, Korean Government decided to implement the medical insurance reimbursement program for full PACS. It has become a turning point for a rapid growth in filmless PACS market. In 2001, Korean Society of PACS set "Guidelines for filmless PACS for medical insurance reimbursement".¹² From then on, large and small hospitals became installed PACS competitively.

In September of this year, 906 medical institutes implemented full PACS in Korea. 55 (128%) out of 43 tertiary hospitals and 265 (99%) out of 268 general hospitals installed full PACS. The percentage more than 100% is because some university hospitals have two hospitals. At present, almost all of university hospitals and general hospitals installed full PACS. On contrary, 14 (8%) out of 163 dental hospitals installed full PACS (Table 1).

The first full dental PACS was installed at Wonkwang University Dental Hospital on November 2002, then followed by Seoul National University Dental Hospital on January 2003.

Table 3. Number of images, examinations and stored data size

No. of institution	No. of examinations per year	No. of digital images per year	Stored data size per year (GB)
1	45,900	189,000	50
2	105,000	470,000	400
3	122,646	318,558	179
4	20,450	406,456	—
5	73,400	1,153,000	230
6	—	—	40
7	46,144	—	—
8	28,083	34,978	100
9	44,303	115,259	82.5
10	—	—	—

Table 4. Image acquisition modalities involved in dental PACS (I)

No. of institution	Extraoral CR imaging units	Extraoral DR imaging units	Intraoral CR imaging units	Intraoral DR imaging units	Occlusal radiograph
1	—	1 (Planmeca)	1 (Kodak CombiX)	3 (Kodak)	○
2	1 (Fuji)	1 (Planmeca)	1 (Digora), 1 (Orex)	6 (Schick)	○
3	2 (Fuji)	—	1 (Kodak CombiX)	15 (Imaging), 1 (Kodak)	○
4	1 (Agfa)	1 (Imaging), 1 (Planmeca)	1 (Kodak CombiX)	4 (Schick)	○
5	1 (Kodak)	1 (Planmeca)	1 (Orex)	3 (Suni), 5 (Kodak)	○
6	1 (Kodak)	1 (Planmeca)	1 (Orex)	8 (Kodak)	○
7	1 (Agfa)	1 (Imaging)	—	2 (Suni), 3 (Kodak)	×-
8	1 (Kodak)	1 (Planmeca)	—	3 (Kodak)	×
9	1 (Fuji)	—	1 (Digora)	4 (Vatech)	×
10	1 (Kodak)	1 (Kodak)	1 (Orex)	8 (Kodak), 2 (Sirona)	○

Table 5. Image acquisition modalities involved in dental PACS (II)

No. of institution	CT units	CBCT units	Ultrasound scan	Photo image	Microscopic image
1	—	1 CBCT (Asahi)	×	×	×
2	1 CT (Siemens)	—	○	○	×
3	1 CT (GE medical)	—	×	×	×
4	—	1 CBCT (Asahi)	×	×	×
5	—	1 CBCT (Hitachi)	○	○	×
6	—	1 CBCT (Asahi)	○	×	×
7	—	1 CBCT (Hitachi)	×	○	×
8	—	1 CBCT (Vatech)	×	×	×
9	1 CT (Siemens)	—	×	×	×
10	—	1 CBCT (Asahi), 1 CBCT (Hitachi)	×	○	×

Table 6. Technologic factors in dental PACS (I)

No. of institution	OS of main server	OS of client	Main DB	Network	Storage
1	Unix	Window	Oracle	Fast ethernet	Hard disc
2	Window	Window	Sybase	Fast ethernet	Hard disc
3	Window	Window	Oracle	Gigabit/Fast ethernet	Hard disc
4	Window	Window	Oracle	Fast ethernet	Hard disc
5	Unix	Window	Oracle	Gigabit/Fast ethernet	Hard disc
6	Unix	Window	Oracle	Fast ethernet	Hard disc
7	Window	Window	Oracle	Fast ethernet	Hard disc
8	Unix	Window	Oracle	Fast ethernet	Hard disc
9	Window	Window	Oracle	Gigabit/Fast ethernet	Hard disc
10	Unix	Window	Oracle	Gigabit ethernet	Hard disc

Table 7. Technologic factors in dental PACS (II)

No. of institution	DICOM employment	HIS coupling	RIS coupling	OCS coupling	EMR coupling	Primary diagnosis usage	Reference display only
1	○	○	○	○	×	○	×
2	○	○	○	○	×	○	×
3	○	○	○	○	○	○	×
4	○	○	○	○	×	○	×
5	○	○	○	○	○	○	×
6	○	○	○	○	×	○	×
7	○	○	○	○	×	○	×
8	○	○	○	○	○	○	×
9	○	○	○	○	○	○	×
10	○	○	○	○	○	○	×

Table 8. Image display and output system (I)

No. of institution	No. of diagnostic display monitor	Type of diagnostic display monitor	Type of clinical display monitor
1	2	1 two-monitor (3M), 1 two-monitor (2M)	15" color
2	3	1 two-monitor (5M), 1 two-monitor (3M), 1 four-monitor (1M)	17" color LCD
3	4	4 two-monitor (5M)	17", 18" color LCD
4	3	3 two-monitor (5M)	19" color LCD
5	10	2 two-monitor (5M), 8 two-monitor (2M)	17" color LCD
6	4	2 two-monitor (5M), 2 one-monitor (3M)	15", 17" color LCD
7	3	2 two-monitor (5M), 1 two-monitor (3M)	17" color LCD
8	1	1 two-monitor (5M)	17" color LCD
9	1	1 two-monitor (5M)	17" color LCD
10	3	1 two-monitor (5M), 2 two-monitor (2M)	17", 20" color LCD

At present (November 2008), 10 out of 11 dental university hospitals installed full PACS.

Table 2 shows the general information of dental PACS in Korean dental university hospitals. The most recent dental PACS was placed this month. PACS vendors at the beginning were four companies, all of which were domestic. However, now those are only two companies. Especially one company manages the almost all of dental university hospitals, except only one. We had more than 20 domestic PACS vendors sev-

eral years ago, but many of them were merged into other companies. The number of dental unit chairs is from 60 to 280. And the number of computers connecting to PACS server is from 55 to 300.

Table 3 shows the number of images, examinations and stored data size. The number of examinations per year was from about 20,000 to about 122,000. The number of digital images per year was from about 35,000 to about 1.1 million. And stored data size was from 40 GB to 400 GB. Some hos-

Table 9. Image display and output system (II)

No. of institution	CD writer	Use of laser imager
1	For transfer to other hospital	×
2	For transfer to other hospital	For dept of Orthodontics
3	For transfer to other hospital	For transfer to other hospital
4	For transfer to other hospital	×
5	For transfer to other hospital	For dept of Orthodontics, For transfer to other hospital
6	For transfer to other hospital	×
7	For transfer to other hospital	For dept of Orthodontics, For dept of OMF Surgery
8	For transfer to other hospital	×
9	For transfer to other hospital	×
10	For transfer to other hospital	For dept of Orthodontics, For dept of OMF Surgery

× means they have no this equipment.

pital stored image data with no compression and the others with lossless compression. The hospital with the most recently installed PACS, tenth hospital, did not have these data.

Table 4 shows image acquisition modalities involved in dental PACS. Almost all of dental university hospitals have CR imaging units for extraoral radiography: four Kodak, three Fuji and two Agfa CR units. And also they have DR imaging units for extraoral radiography. For intraoral radiography, most hospitals have Kodak or Orex CR imaging units. They are mainly used for occlusal radiography. For periapical radiography, all hospitals have DR sensors from 3 to 16. There are three hospitals which do not involve occlusal radiography in dental PACS.

Table 5 also shows image acquisition modalities involved in dental PACS. All hospitals have medical CT or CBCT units. Hospitals which involve ultrasound scan image are three. And hospitals which involve photo image are four. However, there is no one which involves microscopic image.

Table 6, 7 show technologic factors in dental PACS. Operating system (OS) of main server is Unix in 5 and Window in 5. And OS of client is Window in all hospitals. Almost all of hospitals have Oracle as main Data Base (DB). Network was a gigabit ethernet in 1, gigabit/fast ethernet in 3 and fast ethernet in 6. And storage in all hospitals was hard disc type. And dental PACS in all hospitals are DICOM-based and integrated with Hospital Information System (HIS)/Radiology Information System (RIS)/Order Communication System (OCS). And dental PACS coupled with Electronic Medical Record (EMR) were 5. All of them are used for the primary diagnosis, not for the reference display only.

Table 8 shows image display and output system. Almost all

of hospitals have more than one set of 5 mega pixel, high resolution two monitor diagnostic display system. It is because "Guidelines for filmless PACS for medical insurance reimbursement" requires more than 1 set of 5 mega pixel two-monitor system. And type of clinical display monitor was mainly 17" color LCD monitor.

And as output system, all the hospitals have CD writer used for the transfer image data to other hospital. And half of them have Laser imager, which is mainly used for the hardcopy for department of Orthodontics (Table 9).

Future Perspectives of Dental PACS

PACS provides windows to the "all-digital hospital". Through an integration of HIS/RIS/EMR and pathologic imaging DB, PACS will be an excellent and powerful information source for imaging research and education. And web PACS to allow access to electronic patient records through internet will be predominated. However, high levels of network security should be first resolved. Through embedding computer-aided diagnosis technology in PACS, automated diagnosis using artificial intelligence will come true. And through embedding 3D imaging technology like simulation, image-guided treatment in PACS, use of this technology will be widely diffused.

Acknowledgements

The author would like to express her appreciation to the following professors of Korean dental university for the information they provided on their PACS system: Wan Lee, Sam-Sun Lee, Hyok Park, Kyoung-A Kim, Jin-Soo Kim, Yong-Suk Choi, Chang-Hyeon An, Yun-Hoa Jung, Byung-Cheol Kang.

References

1. Choi HS. The evolution of filmless PACS in Korea. *J Korean Soc PACS* 2002; 8 : 69-76.
2. Pare G, Trudel MC. Knowledge barriers to PACS adoption and implementation in hospitals. *Int J Med Inform [Internet]* 2007 [cited 2008 Nov 7]; 76: 22-33. Available from: http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6T7S-4J8CXGJ-1&_user=404015&_rdoc=1&_fmt=&_orig=search&_sort=d&view=c&_acct=C000019118&_version=1&_urlVersion=0&_userid=404015&md5=1c042800808b0ef9cfe9d1f9713dfb59.
3. Kim JH. PACS. In: Korean Society of Medical Informatics. *Health Informatics*. Seoul: Hyunmoon Sa; 1999. p. 463-77.
4. Dove SB, McDavid WD, Welander U, Tronje G, Wilcox CD. Design and implementation of an image management and communications system (IMACS) for dentomaxillofacial radiology. *Dentomaxillofac Radiol* 1992; 21 : 216-21.

5. Chen SK, Yu KM, Chen RS, Hsieh CC. Implementation of an oral and maxillofacial radiology image management and communication system. *Dentomaxillofac Radiol* 1998; 27 : 358-62.
6. Farman AG. Applying DICOM to dentistry. *J Digit Imaging* 2005; 18 : 23-7.
7. Okamura K, Tanaka T, Yoshiura K, Tokumori K, Yuasa K, Kanda S. Integration of a picture archiving and communication system with videocapture and computed radiography in a dental hospital. *Dentomaxillofac Radiol* 2001; 30 : 172-8.
8. Gotfredsen E, Wenzel A. Integration of multiple direct digital imaging sources in a picture archiving and communication system (PACS). *Dentomaxillofac Radiol* 2003; 32 : 337-42.
9. Park H, Jeong HK, Kim KD, Park CS. A planning for clinical application of dental full PACS system in dental general hospital. *J Korean Soc PACS* 2005; 11 : 1-10.
10. Iwasaki H, Honda E, Nishitani H, Takahashi H, Yamamoto Y, Ooguro T, et al. Hanging protocol and viewers for a dental full picture archiving and communication system (PACS). *Dentomaxillofac Radiol* 2007; 36 : 285-95.
11. Nair MK, Pettigrew JC, Loomis JS, Bates RE, Kostewicz S, Robinson B, et al. Enterprise-wide implementation of digital radiography in oral and maxillofacial imaging: The University of Florida Dentistry System. *J Digit Imaging* Published online: 3 September 2008 doi 10.1007/s10278-008-9149-5.
12. PACS guidelines recommended by Korean Society of PACS in 2001. [homepage on the Internet]. Seoul: Korean Society of Imaging Informatics in Medicine; c1994-2004 [updated 2005 Jan 6; cited 2008 Nov 7]. Available from: <http://www.ksim.org>.
13. Current status of medical equipments [database on the Internet]. Seoul: Health Insurance Review & Assessment Service; c2007 [cited 2008 Nov 7]. Available from: <http://www.hira.or.kr>.