REMOTE REAL-TIME MONITORING OF FREE FLAPS VIA SMARTPHONE PHOTOGRAPHY AND 3G WIRELESS INTERNET: A PROSPECTIVE STUDY EVIDENCING DIAGNOSTIC ACCURACY

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This prospective study was designed to compare the accuracy rate between remote smartphone photographic assessments and in-person examinations for free flap monitoring. One hundred and three consecutive free flaps were monitored with in-person examinations and assessed remotely by three surgeons (Team A) via photographs transmitted over smartphone. Four other surgeons used the traditional in-person examinations as Team B. The response time to re-exploration was defined as the interval between when a flap was evaluated as compromised by the nurse/house officer and when the decision was made for re-exploration. The accuracy rate was 98.7% and 94.2% for in-person and smartphone photographic assessments, respectively. The response time of 8 ± 3 min in Team A was statistically shorter than the 180 ± 104 min in Team B ($P = 0.01$ by the Mann–Whitney test). The remote smartphone photography assessment has a comparable accuracy rate and shorter response time compared with in-person examination for free flap monitoring. ©2011 Wiley-Liss, Inc. Microsurgery 00:000–000, 2011.

The development of smartphone technology, with mobile high-speed Internet access and high-resolution photographic capability, has triggered a new era of real-time communication in healthcare. The timing is opportune, as the Joint Commission on Accreditation of Healthcare Organizations (JCAHO) has indicted poor communication as a major cause of medical errors and compromised patient care.[1] Efforts to facilitate communication might therefore be expected not only to make the jobs of healthcare providers easier but also to improve patient outcomes. Although several commercial applications have been introduced to capitalize on this expectation, firm evidence of their efficacy remains scant.[2]

One arena in which smartphone communication holds particular appeal is in the postoperative monitoring of microvascular free tissue transplantations (free flaps). Because failure of a free flap is almost always caused by postoperative thrombosis of the artery or vein, early identification of vascular compromise is imperative to maximize successful outcomes.[3,4] Clinical examination of the transplanted tissue's color, temperature, turgor, and recapillarization continues to be the gold standard of monitoring but requires a high level of experience to be proficient.[5] Experienced surgeons face time constrictions that preclude serial in-person physical examinations, and only a few specialized centers benefit from nurses who are suitably experienced to make an accurate diagnosis of vascular compromise.[6] In response to this problem, a host of products and techniques have been introduced, such as the implantable Doppler probe (Cook-Swartz Doppler Flow Monitoring System®), transcutaneous Doppler probe, tissue oxygenation monitors (O2C®, ViOptix®, and Licox®), and reflectance photoplethysmography. However, these modalities are relatively expensive and cumbersome and are typically used only in well-funded, highly specialized centers.[7]

A smartphone may represent a simple solution to this problem, permitting immediate photographic communication between the nurse or house officer and attending surgeon without the need for special equipment. A prospective evaluation of the practicality, reliability, and accuracy of this method of remote free flap monitoring, in comparison to standard methods, was the purpose of this study.

METHODS

Ethical permission for this study was approved by the Institutional Review Board at Chang Gung Memorial Hospital. Informed consent was obtained preoperatively from each patient for digital photographs to be taken and transmitted between members of their healthcare team for the purposes defined by the study. Between May and June 2009, 100 consecutive patients were prospectively

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recruited, including 83 males and 17 females, with a mean age of 48.8 ± 23 years (range 13–83 years). Within this population, 103 free flaps were performed for reconstruction of defects involving the head and neck, breast, or extremities. A variety of flaps were used, including the anterolateral thigh flap, fibula septocutaneous flap, radial forearm flap, deep inferior epigastric perforator flap, gracilis myocutaneous flap, tensor fascia lata myocutaneous flap, medial sural artery perforator flap, transverse rectus abdominis myocutaneous flap, anteromedial thigh flap, and vastus lateralis myocutaneous flap. All flaps had a visible skin paddle that could be used for monitoring. Sixty-three of the recipient sites were entirely intraoral, whereas the remaining 40 were external. Cases were attended by seven board-certified plastic surgeons. Three of these surgeons, including one senior surgeon (M.H.C., more than 10-year experience), one intermediate surgeon (C.K.T., 5–10 years), and one junior surgeon (J.J.H., less than 5 years), served as assessors of the photographs of all cases (theirs and those of the other surgeons) as Team A. The other four surgeons (two seniors, one intermediate, and one junior) used the traditional in-person examinations for flap monitoring as Team B.

The smartphone used for this study was the iPhone® 3G (Apple, Cupertino, CA). This device has a 2-megapixel camera and a 3.5-in. display with a resolution of 480 × 320 pixels (163 pixels/in.). All photographs were taken using the standard settings of the camera, with no external flash or macrolens. A standardized color card was designed and included in all photographs to compensate for variable lighting conditions and to provide a reference for the assessments.

Patients were observed in the microsurgical intensive care unit for 5 days after their operation, per institutional routine. The flaps were assessed in traditional standard fashion, with serial in-person physical examinations by nurses and house officers, usually every hour on postoperative day 1, every 2 hours on day 2, and every 4 hours from days 3 to 5. The house officer will inform the surgeon immediately if the flap circulation develops signs of compromise by the in-person physical examinations. Beginning on the first postoperative day, a photograph of the flap was taken by one of the two photographers (one data manager, C.Y.L., and one house officer, P.Y.C.) in each morning and afternoon, and additionally at any time that flap compromise was suspected. Each photograph was immediately transmitted via encrypted email with 3G wireless Internet connection in the smartphone to the three assessors, who independently rated their assessments of the flap condition as follows: pink and full as "healthy," pale and shrinking skin turgor as "arterial insufficiency," darker color skin and oozing as "venous insufficiency," and blurred picture or loss of focus as "uninterpretable" (i.e., image of insufficient quality, typically due to bad lighting or focus). Examples of photographs from each rating category are shown in Figure 1.

Decisions to return to the operating room for re-exploration of compromised flaps were ultimately made by the previous operating surgeons with in-person physical examination by the nurses and house officers. These decisions were made without knowledge of the other surgeons' assessments. (Naturally, each assessor's own smartphone assessment was factored into his/her decision to explore his/her own case, but was not disclosed in the other surgeons' cases.) The flaps that were taken to the operating room for re-exploration were referred to as Group A. The other flaps that were not re-explored were referred to as Group B.

The response time to re-exploration was defined as the interval between when a flap was evaluated as perfusion compromised by nurses/house officer and when the decision was made for re-exploration (either by traditional means of communication or by smartphone photography). In cases of flap failure, smartphone photography and assessments were stopped.

Photographic assessments were compiled and compared with actual flap outcomes to determine the accuracy rate. Inter-rater reliability of the photographic assessments was determined, subgroup analysis was performed for intraoral versus external flaps, and outcomes were compared between surgeons using smartphone assessment (Team A) and those not using smartphone assessment (Team B).

RESULTS

On the basis of traditional in-person examinations, nine flaps (Group A) were returned to the operating room for suspected vascular insufficiency. Of these, eight were actually found to have a problem with the artery and/or vein insufficiency, and one was found to be normal. Four flaps were successfully salvaged and other four flaps failed. Of the remaining 94 flaps (Group B) that were not re-explored, one flap failed. The overall success rate was 95.1% (98/103). The re-exploration rate was 8.7% (9/103). The correct assessments were 5,155 (133 in Group A and 5,022 in Group B), and the incorrect assessments were 69 (15 in Group A and 54 in Group B) in in-person examinations, giving an accuracy rate of 98.7% (Table 1).

A total of 1,008 photographs were taken, from which 3,024 remote assessments were made by three assessors. (Flaps that failed were no longer photographed, accounting for the discrepancy in the ratio of flaps to photographs and assessments.) The correct assessments were 2,846 (182 in Group A and 2,644 in Group B), and the incorrect assessments were 77 (12 in Group A and 65 in Group B) in smartphone photograph assessments

Figure 1. Examples of free flap monitoring by smartphone photographs assessed as (above left) pink and full as "healthy," (above right) pale and shrinking skin turgor as "arterial insufficiency," (below left) darker color skin and oozing as "venous insufficiency," and (below right) blurred picture or loss of focus as "uninterpretable."

(Table 1). An assessment of "uninterpretable" was made 101 times (3.3%, 101/3,024); for the purpose of analysis of the smartphone, these assessments were counted as inaccurate (to avoid giving credit to the device for producing a poor image). Thus, the overall diagnostic accuracy of remote assessment via photography with the iPhone 3G was 94.1% (Table 1). If the uninterpretable assessments were excluded, the overall diagnostic accuracy in smartphone photograph assessments would be 97.4%.

Inter-rater reliability among the assessors was high. The three assessors made same assessments of 94.6% (954/1,008) with all correct in 918 assessments and all incorrect in 36 assessments of photographs. The assessments were made correctly by two assessors in 3.7% (37 photograph, 6 in Group A and 31 in Group B), one assessor in 1.5% (15 photographs, 4 in Group A and 11 in Group B), and none of the assessors in 0.2% (2 photographs, 0 in Group A and 2 in Group B). Diagnostic accuracy rate in smartphone photograph assessments was very similar for all three assessors: 96.1% (969/1,008) for the senior surgeon, 91.1% (918/1,008) for the intermediate surgeon, and 95.1% (959/1,008) for the junior surgeon (Table 2). For the purpose of the analysis of the assessors, images deemed uninterpretable were defined as incorrect to avoid penalizing the assessors for the smartphone's failings. Notably, the intermediate surgeon made the assessment of "uninterpretable" 66 times, compared with the senior surgeon of 11 times and the junior surgeon of 24 times (Table 2).

The location of the recipient site (intraoral vs. external) influenced the results of the remote assessments. Ninety-nine of the 101 assessments of "uninterpretable" were made in regard to photographs of intraoral flaps. Counting these uninterpretable assessments as inaccurate, the diagnostic accuracy in smartphone photograph assessments for intraoral flaps was 93.1%, whereas that of external flaps was 95.7%.

The rate of re-exploration was similar between Team A using smartphone assessment and Team B using in-person examination (8.7% vs. 8.8%, respectively). However, the mean response time to re-exploration in Team A (8 ± 3 min) was much shorter than Team B (180 ± 104 min; P = 0.01 by the Mann–Whitney test). The salvage rate (i.e., the percentage of re-explored flaps that were saved) was higher (75% vs. 40%, P = 0.5, Fisher's exact test), and the overall failure rate was lower (2.2% vs. 7.1%, P = 0.4, Fisher's exact test) among the former group (Table 3).

Table 1. Comparisons of Accuracy Rate Between In-Person Examinations and Smartphone Assessments for Monitoring of Free Flaps (n = 103 Flaps)

			Real flap outcome		In-person examinations			Smartphone photographs assessments				
Group	No. of flaps	Re-exploration	Compromised	Noncompromised	Assessments	Correct	Incorrect	Pictures	Assessments	Correct	Incorrect	Uninterpretable
A	9	Yes	8	1	148	133 (89.8%)	15 (10.1%)	68	204	182 (89.2%)	12 (6.9%)	10 (4.9%)
B	94	No	1	93	5,076	5,022 (98.9%)	54 (0.1%)	940	2,820	2,664 (94.5%)	65 (2.3%)	91 (3.2%)
Total	103		9	94	5,224	5,155 (98.7%)	69 (1.3%)	1,008	3,024	2,846 (94.1%)	77 (2.5%)	101 (3.3%)
Accuracy rate						5,155/5,244 (98.7%)				2,846/3,024 (94.1%)		

Group A: cases with re-exploration and Group B: cases without re-exploration. The assessment was compared with the true flap outcome as correct or incorrect. The accuracy rate was 98.1% (5,155/5,244) and 94.1% (2,846/3,024) in in-person examinations and smartphone photograph assessments, respectively.

Table 2. Comparisons of the Accuracy Rate Between Assessors 1–3

			Assessments by assessor 1			Assessments by assessor 2			Assessments by assessor 3		
Group	Re-exploration	Pictures	Correct	Incorrect	Uninterpretable	Correct	Incorrect	Uninterpretable	Correct	Incorrect	Uninterpretable
A	Yes	68	65 (95.6%)	3 (4.4%)	0	60 (88.2%)	3 (4.4%)	5 (7.4%)	57 (83.8%)	6 (8.8%)	5 (7.4%)
B	No	940	904 (96.2%)	25 (2.7%)	11 (1.2%)	858 (91.3%)	21 (2.2%)	61 (6.5%)	902 (96%)	19 (2%)	19 (2%)
Total		1,008	969	28	11	918	24	66	959	25	24
Accuracy rate			969/1,008 (96.1%)			918/1,008 (91.1%)			959/1,008 (95.1%)		

Group A: cases with re-exploration and Group B: cases without re-exploration. The assessment was compared with the flap outcome as correct or incorrect.

Table 3. Comparisons of Re-Exploration, Salvage, Success Rates, and Response Time Between Teams A and B

	No. of flaps *n*	Re-exploration *n*	No. of compromised flaps *n*	Response time[b] (min) Mean ± SD (range)	No. of failed flaps *n*	Salvage rate *n* (%)	Success rate *n* (%)
Team A							
Surgeon 1	21	2	2		0	2/2 (100)	21/21 (100)
Surgeon 2	4	1	0		0	1/1 (100)	4/4 (100)
Surgeon 3	21	1	1		1	0/1 (0)	20/21 (95.2)
Subtotal	46	4 (8.7%)	3	8 ± 3 (5–10)	1	3/4 (75)	45/46 (97.8)
Team B							
Surgeon 4	21	0	0		0	NA	21/21 (100)
Surgeon 5	7	1	1		1	0/1 (0)	6/7 (85.7)
Surgeon 6	17	1	1		1	0/1 (0)	16/17 (94)
Surgeon 7	12	3	4[a]		2[a]	2/3 (66.7)	10/12 (83.3)
Subtotal	57	5 (8.8%)	6[a]	180 ± 104 (60–360)	4[a]	2/5 (40)	53/57 (92.9)
Total/mean	103	9	9[a]	129 ± 119 (5–360)	5[a]	5/9 (55.6)	98/103 (95.1)
P between Teams A and B		1		0.01[b]	0.4	0.5	0.4

The response time was defined as the interval between when the surgeon was initially notified that flap was compromised and when the decision was made to re-explore. Salvage rate was defined as the percentage of re-explored flaps that were saved.
[a]*One flap failed without any re-exploration. There was no statistic significance in all the variables in the re-exploration, number of flap failure, salvage, and success rates between two teams using Fisher's exact test.*
[b]*The response time in Team A was statistically shorter than that in Team B (P = 0.01 by the Mann–Whitney test).*

DISCUSSION

Spurred by governmental emphasis on patient safety and outcomes,[1] new technologies are being developed to further healthcare communication. Telemedicine and teleconsultation are well established in the field of radiology, where specialized cross-linked workstations (e.g., the PACS® system) have made communication of radiologic images more convenient and cost effective, ultimately improving patient care.[8] Telemedicine has also been successfully implemented in diabetic clinics, emergency departments, and rural trauma systems.[9–14] With the advent of wireless technologies,[15] these benefits are literally at the fingertips of virtually every practicing physician, in any field, in any part of the world.[16] The "unwired evolution" of telemedicine has begun.[17]

Numerous investigators have looked at the feasibility of "virtual wound care" using digital photography as a monitoring tool. Murphy et al., using a standard digital camera, demonstrated that the remote assessment of routine wounds is equivalent to in-person physical examination.[2] Similar results were described by Halstead et al., in regard to pressure ulcers.[18] Kim et al.[19] reported less agreement between in-person examination and remote assessment of chronic wounds, but nonetheless emphasized that benefits exist for patients who do not have access to routine monitoring by specialized nurses or physicians. These studies are particularly important in an era of escalating healthcare costs and an increasing push toward outpatient care.[20] In the setting of long-term wound care in the elderly, Ratliff et al.[21] demonstrated improved quality of care and patient satisfaction, despite decreased ward round attendance.

Despite the well-described use of telemedicine in wound care, only a few articles have propounded such strategies in other aspects of plastic surgery. Pap et al.[22] and Baldwin and Langton[15] discussed the potential for emailed photographs to augment telephone conversations between residents and attendings. Hsieh et al.[23,24] demonstrated the benefit of telemedicine in assessing the replant potential of amputated fingers, avoiding unnecessary patient transfers.

Recently, Varkey et al.[25] described the use of emailed digital photographs in the monitoring of free flaps. Unlike our study, most of the studies used photographs that were taken with a standard digital camera, downloaded to a computer, and emailed. Such a method is relatively time-consuming and inevitably results in a communication lag. In our opinion, the smartphone is a far more practical and expedient tool. For salvage of a compromised free flap, expediency of diagnosis is paramount. Treatment decisions can be made instantly by the most experienced surgeon regardless of his/her location or busy schedule, and immediate feedback can be provided to the nurses or residents. Benefits can thus be seen in patient care, surgeon productivity, and resident education.

The response time of 8 ± 3 min in Team A using smartphone photography for flap monitoring was statistically shorter than the 180 ± 104 min in Team B using traditional in-person examination (P = 0.01 by the Mann–Whitney test). At our institution, the traditional monitoring method involves observation by the nursing staff, usually every hour on postoperative day 1, every 2 hours on day 2, and every 4 hours from days 3 to 5. If the nursing staff is concerned that the flap may be

Figure 2. The photographs taken from a same flap by the 3G iphone with a 2-megapixel camera and a 3.5-in. display (resolution at 163 pixels/in.) and 4G iphone with 5-megapixel camera, a 3.5-in. display (resolution at 326 pixels/in.) and built-in light-emitting diode flash were compared. Left: photograph from 3G iphone and right: photograph from 4G iphone.

compromised, she/he will inform the house officer, usually the second- or third-year surgical resident, to check the flap. The house officer may then inform the chief resident or microsurgical fellow, who will likewise check the flap and communicate any concerns to the attending surgeon. Finally, the attending surgeon will come to check the flap before making the decision to re-explore. This multistep, hierarchical approach to decision making obviously takes a great deal of time and explains the delayed response time of Team B. On the other hand, the smartphone photographs are sent by either the nurse or the house officer to the attending surgeon directly in a few seconds, and the attending is often able to make the decision for re-exploration immediately. The salvage rate in Team A (75%) was higher than that in Team B (40%), although the number of flap failures was too small in both teams to reach statistical significance ($P = 0.5$). However, the shorter response time and earlier re-exploration can logically be assumed to result in a higher salvage rate and higher success rate. At a minimum, it can be concluded that smartphone photography is much more efficient and at least as effective as traditional flap monitoring.

The major limitation of the smartphone is the quality of its camera. Previous studies using mobile phones for telemedicine were hampered by this factor.[10,11,14,23,24,26–29] Indeed, the device used in this study, the iPhone® 3G, is itself limited in its ability to capture quality photographs under conditions of poor lighting or variable depth of field, as was the case with intraoral flaps in our study. However, technology is progressing rapidly, and new devices have been introduced with much higher resolution, flash capability, and even macrofeatures, such as the iPhone® 4G with 5 megapixels (Fig. 2), Blackberry Torch 9800 with 5 megapixels, HTC Desire with 8 megapixels, Sony Ericsson Xperia ARC with 8 megapixels, and Nokia E7-00 with 8 megapixels. The newest smartphones also have audio and video recording ability that may be sent to the surgeon in the office, operating room, or home to check the flap and to hear the Doppler sounds. The results of our study would probably be further validated or exceeded with the use of these newer devices.

To the best of our knowledge, this is largest and first prospectively designed study proving the feasibility, reliability, accuracy rate, and outcome of real-time remote free flap monitoring. Besides demonstrating an overall diagnostic accuracy comparable to traditional in-person examination, remote assessment produced an extremely low inaccuracy rate of 5.9% (2.5%, if the uninterpretable 3.3% was excluded), which is the most critical measure of safety. Furthermore, our study demonstrated a very high-inter-rater reliability among three different surgeons as the assessors of varying experience, implying that this method could be widely implemented in many centers with similar success.

An important related issue was recently discussed by Rohrich et al. and Allert et al., who highlighted the potentially potent medical–legal issues surrounding the transmission of patient photographs over the Internet.[23,30] However, in virtually, all cases of microvascular free tissue transfer, the area of interest (i.e., the skin paddle of the free flap) is not by itself identifiable health information. Patient confidentiality should therefore not be at risk, provided additional identifiers are not included in or appended to the transmitted photographs. The use of encrypted email may be necessary, depending on legal and institutional regulations.

Besides free flap monitoring, the high accuracy of smartphone assessment shown in our study may translate well to other fields of medicine, such as diabetic clinics, emergency department consultations, rural trauma systems, replantations, and home nursing wound care.

CONCLUSIONS

This prospective study demonstrated that remote, real-time monitoring of free flaps via smartphone photography is feasible, reliable, and safe. The accuracy rate of remote assessments of free flap monitoring via smartphone photography was comparable to in-person examination. The smartphone photograph assessments were consistent between different assessors. The response time of smartphone communication for free flap monitoring was statistically shorter than the traditional method. Smartphone communication therefore has the potential to improve patient care.

REFERENCES

1. Clinton HR, Obama B. Making patient safety the centerpiece of medical liability reform. N Engl J Med 2006;354:2205–2208.
2. Murphy RX Jr, Bain MA, Wasser TE, Wilson E, Okunski WJ. The reliability of digital imaging in the remote assessment of wounds: Defining a standard. Ann Plast Surg 2006;56:431–436.
3. Bui DT, Cordeiro PG, Hu QY, Disa JJ, Pusic A, Mehrara BJ. Free flap reexploration: Indications, treatment, and outcomes in 1193 free flaps. Plast Reconstr Surg 2007;119:2092–2100.
4. Chen KT, Mardini S, Chuang DC, Lin CH, Cheng MH, Lin YT, Huang WC, Tsao CK, Wei FC. Timing of presentation of the first signs of vascular compromise dictates the salvage outcome of free flap transfers. Plast Reconstr Surg 2007;120: 187–195.
5. Disa JJ, Cordeiro PG, Hidalgo DA. Efficacy of conventional monitoring techniques in free tissue transfer: An 11-year experience in 750 consecutive cases. Plast Reconstr Surg 1999;104:97–101.
6. Krieger LM, Lee GK. The economics of plastic surgery practices: Trends in income, procedure mix, and volume. Plast Reconstr Surg 2004;114:192–199.
7. Luu Q, Farwell DG. Advances in free flap monitoring: Have we gone too far? Curr Opin Otolaryngol Head Neck Surg 2009;17: 267–269.
8. Fridell K, Edgren L, Lindskold L, Aspelin P, Lundberg N. The impact of PACS on radiologists' work practice. J Digit Imaging 2007;20:411–421.
9. Parasyn A, Hanson RM, Peat JK, De Silva M. A comparison between digital images viewed on a picture archiving and communication system diagnostic workstation and on a PC-based remote viewing system by emergency physicians. J Digit Imaging 1998;11:45–49.
10. Chu Y, Ganz A. A mobile teletrauma system using 3G networks. IEEE Trans Inf Technol Biomed 2004;8:456–462.
11. Chu Y, Ganz A. A mobile teletrauma system for rural trauma care. Conf Proc IEEE Eng Med Biol Soc 2004;5:3282–3285.
12. Farmer A, Gibson OJ, Tarassenko L, Neil A. A systematic review of telemedicine interventions to support blood glucose self-monitoring in diabetes. Diabet Med 2005;22:1372–1378.
13. Verhoeven F, van Gemert-Pijnen L, Dijkstra K, Nijland N, Seydel E, Steehouder M. The contribution of teleconsultation and videoconferencing to diabetes care: A systematic literature review. J Med Internet Res 2007;9:e37.
14. Belala Y, Issa O, Gregoire JC, Wong J. A secure mobile multimedia system to assist emergency response teams. Telemed J E Health 2008;14:560–569.
15. Baldwin AJ, Langton SG. Postoperative monitoring of flaps by digital camera and Internet link. Br J Oral Maxillofac Surg 2001; 39:120–121.
16. Zbar RI, Otake LR, Miller MJ, Persing JA, Dingman DL. Web-based medicine as a means to establish centers of surgical excellence in the developing world. Plast Reconstr Surg 2001;108:460–465.
17. Tachakra S, Wang XH, Istepanian RS, Song YH. Mobile e-health: The unwired evolution of telemedicine. Telemed J E Health 2003; 9:247–257.
18. Halstead LS, Dang T, Elrod M, Convit RJ, Rosen MJ, Woods S. Teleassessment compared with live assessment of pressure ulcers in a wound clinic: A pilot study. Adv Skin Wound Care 2003; 16:91–96.
19. Kim HM, Lowery JC, Hamill JB, Wilkins EG. Accuracy of a web-based system for monitoring chronic wounds. Telemed J E Health 2003;9:129–140.
20. Ong CA. Telemedicine and wound care. Stud Health Technol Inform 2008;131:211–225.
21. Ratliff CR, Forch W. Telehealth for wound management in long-term care. Ostomy Wound Manage 2005;51:40–45.
22. Pap SA, Lach E, Upton J. Telemedicine in plastic surgery: E-consult the attending surgeon. Plast Reconstr Surg 2002;110:452–456.
23. Rohrich RJ. The Web and your cosmetic surgery practice. Plast Reconstr Surg 2001;107:1253–1254.
24. Hsieh CH, Tsai HH, Yin JW, Chen CY, Yang JC, Jeng SF. Teleconsultation with the mobile camera-phone in digital soft-tissue injury: A feasibility study. Plast Reconstr Surg 2004;114:1776–1782.
25. Varkey P, Tan NC, Girotto R, Tang WR, Liu YT, Chen HC. A picture speaks a thousand words: The use of digital photography and the Internet as a cost-effective tool in monitoring free flaps. Ann Plast Surg 2008;60:45–48.
26. Tsai HH, Pong YP, Liang CC, Lin PY, Hsieh CH. Teleconsultation by using the mobile camera phone for remote management of the extremity wound: A pilot study. Ann Plast Surg 2004;53:584–587.
27. Kim DK, Yoo SK, Kim SH. Instant wireless transmission of radiological images using a personal digital assistant phone for emergency teleconsultation. J Telemed Telecare 2005;11 (Suppl 2):S58–S61.
28. Chandhanayingyong C, Tangtrakulwanich B, Kiriratnikom T. Teleconsultation for emergency orthopaedic patients using the multimedia messaging service via mobile phones. J Telemed Telecare 2007;13:193–196.
29. Kim DK, Yoo SK, Park JJ, Kim SH. PDA-phone-based instant transmission of radiological images over a CDMA network by combining the PACS screen with a Bluetooth-interfaced local wireless link. J Digit Imaging 2007;20:131–139.
30. Allert S, Adelhard K, Boettcher F, Schweiberer L. Communication in plastic surgery by means of e-mail: experiences and recommendations for clinical use. Plast Reconstr Surg 2000;106:660–664.