Estimation of date of death through wound healing of an extraction socket: a case report

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Abstract

Surgical extraction of teeth due to dental pathologies is a relatively common procedure in modern man. The healing of the wound that results occurs in gradual and sequential stages, such that the analysis of this repair process can be very useful in forensic investigations on human remains. The following study reports on a particular case where the remodeling of a tooth socket allowed an estimation of the time that had elapsed from the day of the surgical extraction of the tooth to the time of death. The corpse was that of a woman of 34 years. It was in an advanced state of decomposition, as it was largely skeletonized. Macroscopic, radiographic, and histological examinations of the oral cavity showed the initial stages of alveolar bone remodeling of the first left mandibular molar, which was characterized by: (i) a small reduction in the vertical height of the vestibular surface with respect to the theoretical original position of the tooth; (ii) resorption of the intra-alveolar septum and lamina dura; and (iii) formation of new immature bone, which covered the entire inner surface of the socket. This study established that the subject died 13-42 days after the tooth extraction. Knowing the date of the dental extraction provided by the police investigation, it was possible to provide an estimate of the date of death.

Keywords: alveolus; tooth extraction; healing of extraction wound; alveolar bone remodeling; date of death; forensic investigation

1. Introduction

According to Dalitz [1], surgical tooth extraction as a consequence of dental disease is a relatively common procedure in modern man. Healing of the resulting extraction socket appears to progress in an ordered and sequential manner. This can be of great value in forensic investigations of unidentified human remains, as it can provide some degree of accuracy for the estimation of the period of time that has elapsed between the antemortem extraction of a particular tooth and the time of death of that person. If the identity can be established for human remains that have a healing tooth-extraction wound or have bone changes related to the recent removal of teeth, and if the dental history of the subject is known, then this information can provide positive contributory evidence, or indeed negative evidence, toward identification of the time of death [1,2].

The aim of this paper is to report on a case where the remodeling of a tooth socket of a young woman allowed the estimation of the time that had elapsed from the day of the surgical extraction of the tooth to the time of the death of the subject.

2. Case History

2.1. Discovery of the corpse and autopsy findings

On August 26, 2014, a corpse was found among weeds near a pylon under a viaduct of the A14 motorway near the town of Vasto (Chieti province, Italy). The corpse was in an advanced state of decomposition, as it was largely skeletonized. In particular, the cranium, thorax and upper limbs were completely skeletonized, while the pelvis and lower limbs showed mummified soft tissues (Fig. 1). These were characterized by a parchment-like texture (i.e., ‘old leather’) and were strongly attached to the skeleton. External and internal examination of the corpse revealed

no pathological findings. Toxicological examinations did not reveal any extra relevant details concerning use of alcohol or pharmaceuticals, or of drugs of abuse.

A few days later, the corpse was identified through DNA analysis. According to the information from the police and the forensic investigation, the corpse belonged to a woman of 34 years who had gone missing in Vasto on March 28, 2014.

On September 12, 2014, at the morgue of the Vasto cemetery, our expert working group in physical anthropology analyzed the corpse to evaluate the presence of possible skeletal injuries and/or other evidence that might be linked to the cause of death. The delay between the autopsy and the physical anthropological investigation was the consequence of the absence of involvement in Chieti province of physical anthropologists in the initial stages of the forensic work, including the recovery of skeletal remains, determination of the postmortem interval, and the identification procedure. When the forensic investigation is at a standstill, the forensic pathologist will sometimes contact the forensic anthropologist.

2.2. Physical anthropological examination

Detailed macroscopic examination of the mummified areas and the single bone elements indicated that they were well preserved, and that there were no signs of traumatic lesions or other skeletal evidence that might have been correlated to the cause of death. During the macroscopic examination of the oral cavity, the absence of nine permanent teeth was recorded: three in the maxilla (i.e., second left premolar, two third molars), and six in the mandible (i.e., two first and second premolars, first left molar, third left molar) (Fig. 2). The macroscopic analysis that was carried out *in situ* in the morgue of Vasto cemetery did not allow any assessment of whether the absence of the three third molars was antemortem (i.e., whether the respective sockets were completely remodeled) or whether they corresponded to agenesia (i.e., whether they were due to the lack of formation of the dental germs during tooth development). The maxillary second left premolar and the two first and second premolars of the

mandible were lost postmortem, because there were no signs of alveolar bone remodeling. However, it was noted that the socket of the mandibular left first molar showed the initial stages of bone remodeling. This observation allowed the possibility to ascertain the time of death of the subject if the dental history records of the missing person could be obtained. Therefore, our investigation was focused on an analysis of this single socket, which is detailed in this case report.

After photographic documentation of the oral cavity, we proceeded to isolate the region that contained the socket of the mandibular first molar using a vibrating saw, to allow a more detailed study in the laboratory. The mandibular fragment was subjected to macroscopic morphological examination, and radiographic and histological analysis. A radiographic image of the anteroposterior view was obtained by X-ray analysis (45 kV, 5 mAsH) at the Department of Radiology of the Villa Serena Hospital (Città S. Angelo, Pescara, Italy), and it was examined by a radiologist. Histological sections of the untreated mandibular sample (non-decalcified and not embedded in resin) were produced using a microtome (SP1600; Leica) with a diamond blade. The relevant tooth socket was sectioned at the level of the impression of the mesial root of the molar. Unstained thin sections of 60 μm and 100 μm thickness were obtained, which were observed at 40× magnification under an optical microscope (BX41; Olympus). The images were captured using a digital camera (Moticam 2300) connected to the optical microscope. The histological sections were performed by physical anthropologists at the University Museum of 'G. d'Annunzio' University of Chieti–Pescara (Italy).

The healing phase and the related survival time after extraction was estimated using the time sequences of tissue regeneration in human extraction wounds that have been reported in the literature [1–14]. Complementary analyses (i.e., degree of decomposition of the corpse, forensic entomology analysis) were also performed at the Section of Legal Medicine (Department of Medicine and Aging Sciences, 'G. d'Annunzio' University of Chieti–Pescara), to estimate the date of death of the subject [15,16].

3. Results

3.1. Description of the observed signs of alveolar bone remodeling

3.1.1. Macroscopic description

The alveolar ridge was at an early stage of remodeling, and it showed a slight reduction in the vertical height of the vestibular surface with respect to the theoretical original position of the tooth (Fig. 3a). Considerable remodeling activity was observed, with resorption of the intra-alveolar septum and the lamina dura, and formation of new immature bone. This immature bone tissue covered the entire inner surface of the socket, which included the apical regions, the walls, and the region of the intra-alveolar septum (Fig. 3b).

3.1.2. Radiological description

The cortical bone of the alveolar process showed resorption at the level of the alveolar ridge and the walls of the socket. The intra-alveolar septum was in the process of resorption, and a small degree of intra-alveolar radiopacity extended from the walls to the center of the socket. About a quarter of the apical third of the socket was occupied by this radiodense tissue (Fig. 4).

3.1.3. Histological description

The entire inner surface of the socket was covered with woven bone, with some osteocytes visible within the immature bone. Lamellar bone appeared to be absent. Most of the socket was empty and had probably been occupied by provisional connective tissue and granulation tissue, which would have disappeared as a consequence of the decomposition process.

There were also evident differences in the composition and structural organization of the reparative bone tissue compared to the basal bone tissue of the mandible. The basal bone

tissue was fully organized, while the newly formed tissue had remained very unorganized (Fig. 5).

3.2. Estimation of the time of death of the subject

3.2.1. Wound healing of the extraction socket

We considered the date of the tooth extraction provided by the police investigation as the reference time. We were informed that the subject had undergone dental surgery on March 15, 2014, for extraction of the mandibular left first molar.

According to the radiological findings, the time that had lapsed from the tooth extraction to the death of the subject was estimated to be between 21 days and 38 days [1–4,6,13]. The histological analysis suggests a time sequence of osseous repair of from 13 days to 42 days [4,5,7–14]. Thus, the maximum range of time between the tooth extraction and the time of death of this subject was estimated as from 13 days to 42 days (Table 1). Therefore, as the tooth extraction took place in March 2014, we estimated that the death of the subject was most likely to have occurred in the period between March 28 and April 26, 2014.

3.2.2. Complementary analyses

Although the police investigation here did not provide any more details, two independent and complementary analyses were performed to estimate the date of death of the subject. These were carried out by researchers who were blinded to the results of the previous analysis during their studies, and they were based on an evaluation of the degree of decomposition of the corpse, and the forensic entomology analysis.

At the time of discovery, the decay of the corpse corresponded to the fourth stage [15], when putrid destruction of the tissues occurs, and a corpse is gradually reduced to a skeleton. Although the forensic literature describes mummification as a process that generally occurs

between 6-12 weeks from the death of a person, there are cases of premature mummification that have been described in central Italy, such as that of Marella et al. [17], whose description matched the present case. The time of death was estimated as at least 8 weeks before the date of the discovery of the corpse, which established a temporal period of before June 31, 2014.

For the entomological evidence, several living specimens and larvae of Coleoptera (i.e., *Corynetes*, *Staphylinidae*) and Lepidoptera were found. Their detection is typical of the third squad according to the Mégnin classification [16]. Based on this entomological evidence, the death occurred from 3 to 6 months prior to the discovery of the body, which defined the period from March 28 to the end of May, 2014.

Figure 6 shows a summary of the chronological period of the events of this medico-legal case, and the estimated date of death of the subject according to the different methodologies used.

4. Discussion

The surgical extraction of a tooth initiates a series of reparative processes that involve both hard tissues (e.g., alveolar bone) and soft tissues (e.g., periodontal ligament, gingiva). The sequence of events that lead to alveolar healing after tooth extraction has been extensively documented, as follows [9,11]: (i) immediately after removal of the tooth, a blood clot with a tight fibrin network fills the socket, and then polymorphonuclear cells and fibroblasts invade the clot; (ii) after 2-3 days, granulation tissue starts to develop; (iii) on the fourth day, epithelial tissue grows out from the edges of the socket, at which point osteoclasts resorb the alveolar ridge; (iv) on the seventh day, connective tissue develops at the base of the socket, which contains a few areas of osteoid tissue; (v) by day 20, re-epithelialization is complete, at which point mineralization starts, to produce woven bone that subsequently undergoes remodeling; and (vi) 40 days after tooth extraction, the ridge height is decreased by about one third.

Although several studies [e.g., 1–14] have delineated the well-defined tendency of each tissue component to change over time, they have also revealed certain limitations, such as great inter-individual variation with respect to tissue formation and maturation. In particular, it has been reported that whereas provisional connective tissue appears to form consistently within the first few weeks of healing, the interval during which the mineralized bone is laid down is much less predictable [12]. This variability in wound healing processes is also paralleled by a large variation in the dimensional alterations to the healing socket. The reason for this variation is at present not understood, and it might be linked to different factors [14,18]. These factors appear to be, at least in part, related to: (i) the patient (e.g., smoking or local diseases, such as advanced periodontal disease, periapical abscess, or granuloma [19,20]); (ii) the tooth site characteristics (e.g., location of edentulous site, single *versus* multiple extractions [21–23]), and (iii) surgical variables (e.g., chlorhexidine administration following tooth extraction, elevation of a full-thickness muco-periosteal flap) [24–26]. In the present case, there were signs of alveolar remodeling at an initial stage, thus minimizing the inter-individual variation of the tissue formation and maturation that is observed in the later stages of alveolar healing that has been described in several studies [e.g., 12].

While the studies cited above can yield valuable information, they also reveal certain limitations for the estimation of the time sequence of tissue regeneration in the healing of extraction wounds, and therefore, they must be considered with caution. The main problems concerning the methodological aspects of these studies relate to: (i) inclusion of tissue samples from systematically diseased individuals, or even cadavers [e.g., 4]; (ii) unclear, or non-standardized, experimental protocols [e.g., 7]; (iii) evaluation of only a few tissue samples [e.g., 4,6,8]; and/or (iv) short observation intervals [e.g., 7,8,10].

However, notwithstanding these limitations, the time sequence that has been developed on the basis of these studies is universally accepted by the scientific community. This is used as the basis of discussions of alveolar socket healing in various current textbooks [e.g.,

27–29] and in the research literature [e.g., 20,30,31]. This time sequence thus forms the basis for the planning of definitive prosthetic, periodontal, and orthodontic clinical treatments that frequently follow in series, or are carried out in concurrence with dental extraction.

In this case report, the radiological methods indicated a narrower range of time between the tooth extraction and the death of the subject than the histological methods. However, there are no comparative studies that demonstrate that such radiology is statistically more precise or accurate than the histology. We applied both of these methods to take into account all of the possibilities, to provide the best estimation of the postmortem interval, and we consider the maximum range as the more appropriate.

5. Conclusions

The overall findings here demonstrate that the healing of this surgical extraction socket followed a pattern similar to that described in the literature according to macroscopic, radiological, and histological examinations of tissues harvested from socket sites in humans. Although the police investigation did not subsequently provide the exact date of the death of the subject, this study reports a case where alveolar bone remodeling allowed the estimation of the period of death. The estimated postmortem interval through wound healing of an extraction socket was consistent with, and more restricted than, the evaluation from the degree of decomposition of the corpse and the forensic entomology analysis.

Thus, tooth socket healing constitutes a potential source of information for the estimation of the time that has elapsed from the day of surgical extraction of a tooth to the time of death of the subject, and this would appear to be more precise than the decay of the corpse and the forensic entomology. With further standardized research in this direction, the information that can be derived from analysis of the wound healing of an extraction socket can provide a valuable tool for use in medico-legal contexts.

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Fig. 1 Detail of the thorax, cranium, and mandible.

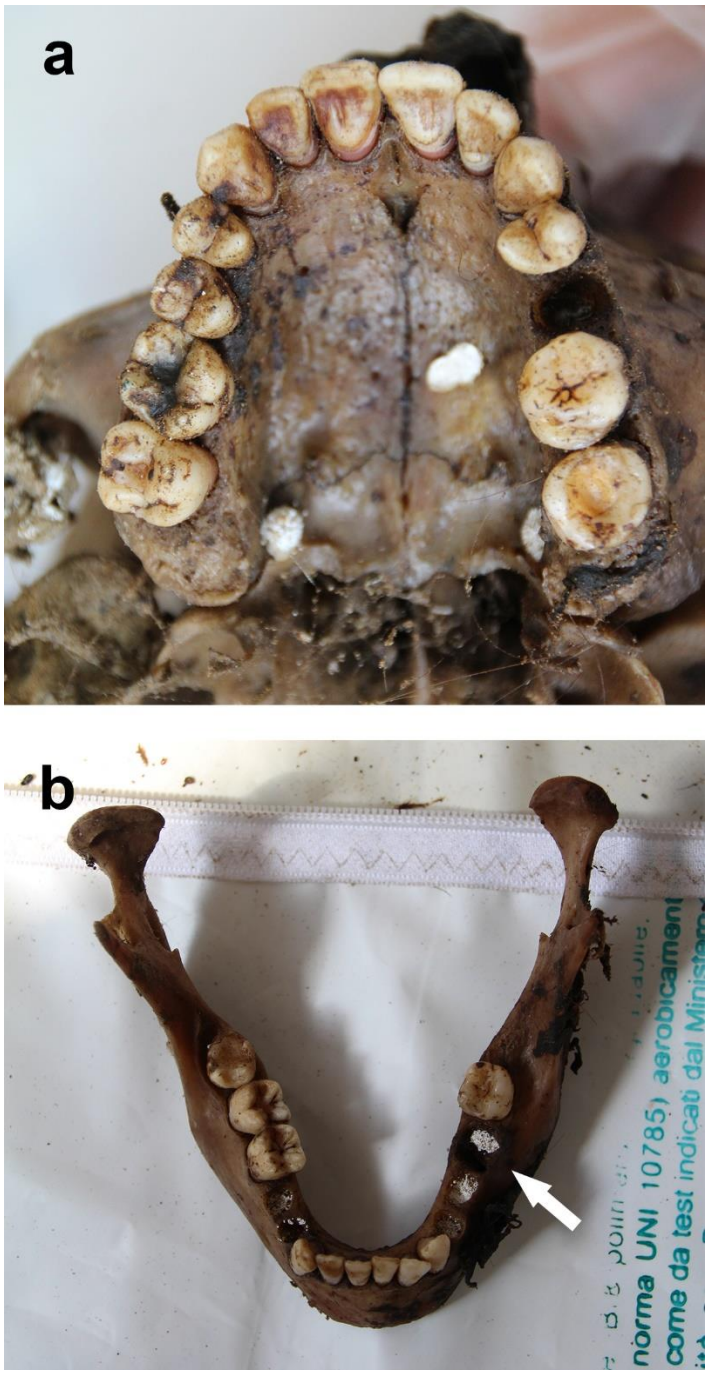

Fig. 2 (a) Maxilla showing the absence of three permanent teeth: the second left premolar, and the two third left molars. **(b)** Mandible showing the absence of six permanent teeth: the two first and second premolars, the first left molar, and the third left molar. For both the maxilla and mandible, the premolars were lost postmortem. The macroscopic analysis *in situ* did not allow determination of whether the third molars were lost antemortem or they were agenetic. The mandibular left first molar (arrow) was lost antemortem, with initial stages of bone remodeling seen.

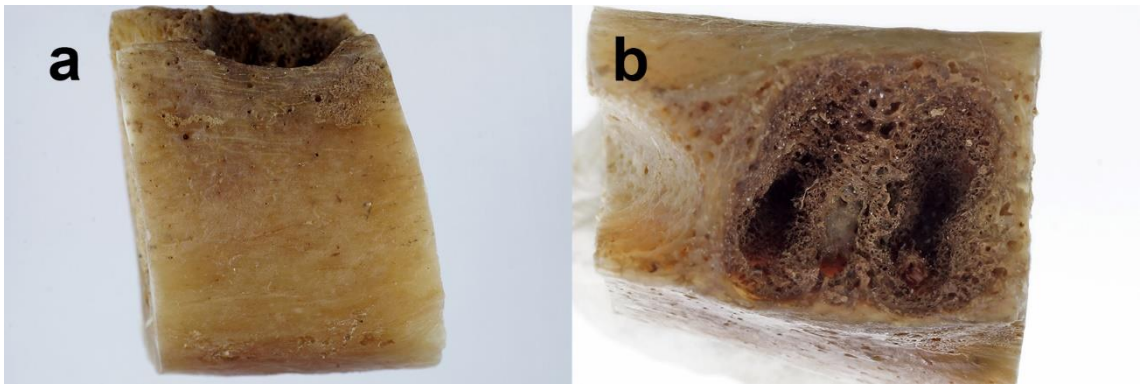

Fig. 3 Mandibular fragment containing the socket of the left first molar. **(a)** Vestibular surface showing a small reduction in the height with respect to the theoretical original position of the tooth. **(b)** Superior view of the socket showing extensive bone remodeling activity, with the resorption of the intra-alveolar septum and lamina dura, and the formation of new immature bone covering the entire inner surface of the socket.

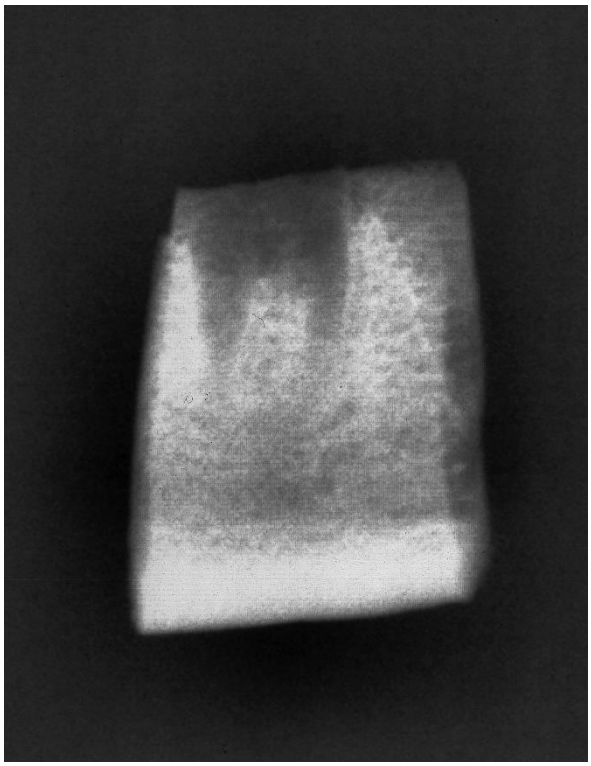

Fig. 4 Radiological image of the socket of the left first molar, showing resorption of the cortical bone of the alveolar process at the level of the alveolar ridge, and the walls of the socket. The formation of new immature bone is also seen, which occupies about a quarter of the apical third of the socket.

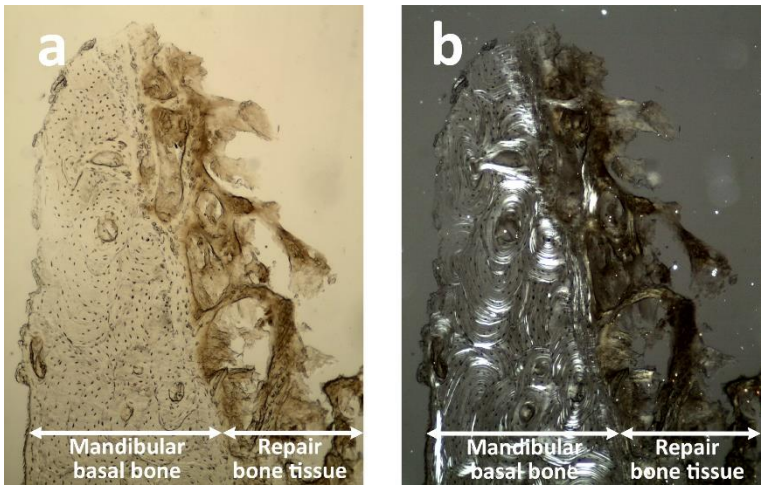

Fig. 5 (a) Histological section at the level of the mesial root of the socket (magnification, 40×). The difference in the composition and structural organization of the repair tissue compared to the basal bone tissue of the mandible is evident. The basal bone tissue is fully organized, while the newly formed tissue is very disorganized. **(b)** The same histological section under polarized light.

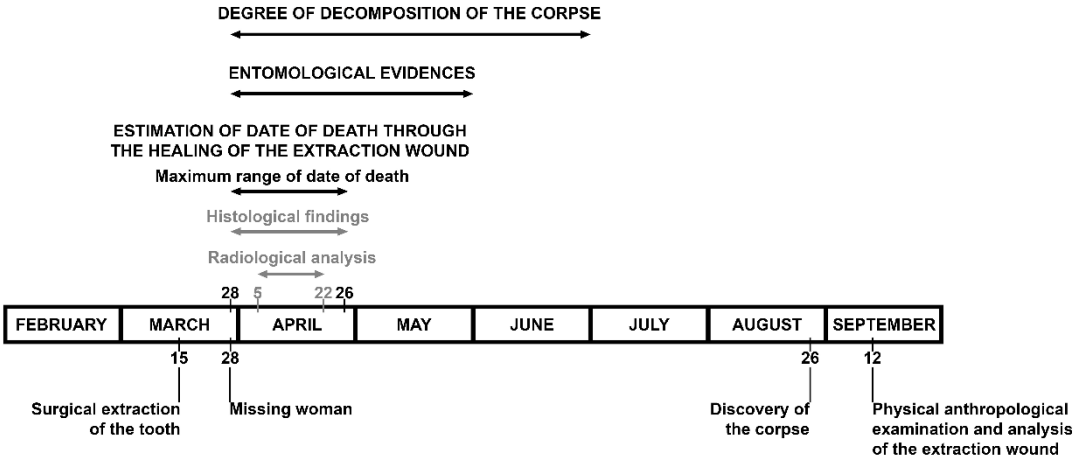

Fig. 6 Illustration of the chronological period of events defined in this medico-legal case, and the estimated date of death of the subject according to the different methodologies used. See text for details.

Table 1. Estimation from the different studies of the time elapsed from the surgical extraction of the tooth to the death of the subject, according to the time sequence of osseous repair of human extraction wounds.

Reference	**Time elapsed from dental extraction (days)**
Kittner (1933) [4]	<28
Mangos (1941) [5]	21-38
Swinburn (1952) [6]	>14
Dawkins (1958) [7]	>28
Amler et al. (1960) [8]	18-20
Dalitz (1964) [3]	21-28
Boyne (1966) [9]	*ca*. 13-16
Amler (1969) [10]	*ca*. 20
Evian et al. (1982) [11]	28-42
Bodic et al. (2005) [12]	*ca*. 20
Trombelli et al. (2008) [13]	14-28
Marzola et al. (2010) [14]	24-35
Morgan (2011) [1]	*ca*. 17-18
Farina and Trombelli (2012) [15]	*ca*. 14-28
Maximum range estimated	**13-42 days**