

Trepanation in Italy: a review

Journal:	<i>International Journal of Osteoarchaeology</i>
Manuscript ID	OA-16-0137.R1
Wiley - Manuscript type:	Research Article
Date Submitted by the Author:	n/a
Complete List of Authors:	Giuffra, Valentina; University of Pisa, Department of Translational Research and New Technologies in Medicine and Surgery Fornaciari, Gino; University of Pisa, Department of Translational Reserches and New Technologies in Medicine and Surgery
Keywords:	trepanning, ancient surgery, drilling, scraping, cutting, perforation

SCHOLARONE™
Manuscripts

Review

Trepanation in Italy: a review

Giuffra Valentina^{1,2}, Gino Fornaciari^{1,2}

¹ *Division of Paleopathology, Department of Translational Research and New Technologies in Medicine and Surgery, University of Pisa, Pisa, Italy*

² *Center for Anthropological, Paleopathological and Historical Studies of the Sardinian and Mediterranean Populations, Department of Biomedical Sciences, University of Sassari, Sassari, Italy*

Corresponding author:

Valentina Giuffra

Division of Paleopathology, Department of Translational Research on New Technologies in Medicine and Surgery, Via Roma 57, 56126 Pisa, Italy; E-mail: v.giuffra@med.unipi.it
Tel.: 0039 050 992894; fax: 0039 050 992706

Running title: Trepanation in Italy

Key words: trepanning, ancient surgery, drilling, scraping, cutting, perforation

Conflict of interest: all authors declare no conflict of interest

Sponsor

This work was supported by a grant from the ARPA Foundation (www.fondazionearpa.it).

Abstract

This paper reviews and discusses cases of skull trepanation in ancient Italy on the basis of information provided by the literature. A total of 54 individuals from 43 different Italian archaeological sites were found to have evidence of trepanation. The analysis of evidences of trepanation in Italy have demonstrated that no differences can generally be perceived between the trepanned individual and the social context of the burial, leading to exclude a special role of the former within the group. Trepanation in Italy covers a time span of approximately 7000 years, the most ancient cases dating back to the 5th millennium BC and the most recent to the 18-19th centuries AD. The geographic distribution appears quite homogeneous, with a prevalence of cases in Central Italy, and abundant evidence from prehistoric Sardinia. The majority of individuals show a single trepanation, whereas others present skulls with multiple holes. Trepanation in Italy was reserved to adult individuals, except for some rare cases, and shows a relevant preponderance for the male sex. The most diffused technique is scraping; cutting and drilling are less attested, especially as unique techniques for trepanation, but they were used more frequently in combination with scraping. Trepanation could in some cases be hypothesized as therapeutic intervention for the treatment of a traumatic wound or of other pathologies, whereas in other cases a number of evidences are attested of trepanation performed as probable ritual intervention or as experimental surgery; in the remaining cases the reasons for trepanation are unclear or not determinable. A high percentage of long-term healing associated with trepanation has been evidenced.

Introduction

Trepanation is considered the most ancient surgical procedure, consisting in the intentional removal of a bone portion of the neurocranium practised during life or *post-mortem*. Scientific attention to this practice dates back to the second half of 19th century, when Paul Broca (1867) first published the discovery of a trepanned skull from Peru. From then on several reports enriched the knowledge of this practice, the evidence of which comes from all continents and ranges from prehistory to present times, being still attested in some African tribes (Margetts, 1967).

In Europe, the technique is largely flourished during the Neolithic period, with particular concentration in Great Britain and France (Piggott, 1940; Roberts & McKinley, 2003; Zanello et al., 2015). Many other findings have been reported in European countries: Denmark (Bennike, 2003), Germany (Weber & Wahl, 2006), Portugal (Crubézy et al., 2001), Scandinavian peninsula (Jennbert, 1991; Holck, 2008), Spain (Campillo, 2007; Lopez et al., 2011), and Turkey (Erdal & Erdal, 2011).

Besides the single cases, some reviews have been published on trepanations found in delimited geographical areas or countries (Rytel, 1956; Stewart, 1958; Verano, 2003; Erdal & Erdal, 2012).

As for Italy, the comprehensive work by Germanà and Fornaciari (1992) and a review article by Fornaciari and Naccarato (1993) need to be updated and had the limit of being accessible only in Italian language.

The present paper thus aims to inform a wider audience by providing an exhaustive overview of the trepanations attested in the Italian territory.

Materials and Methods

A total of 54 individuals from 43 different Italian archaeological sites were found to have evidence of trepanation. The cases were examined on the basis of information provided by the literature; a large part of them (30) were directly examined by one of the authors (GF), the remaining cases were identified in the literature only (24). Two further cases were attested from Bozzolo (province of

1
2
3 Mantova) and Montichiari (province of Brescia), dated back respectively to the Etruscan Age (5th
4 century BC) and to the Langobardic period (7th century AD), but no other details can be evinced
5 from the abstract in which they were published (Mazzucchi et al., 2009), and therefore they will not
6 be included in this review. Another trepanation, detected in cremated remains from 2nd century
7 Rome, has also been ruled out as the case seems to be doubtful, judging from the photographic
8 documentation (Charlier et al., 2014).

9
10
11
12
13
14
15
16 Various conditions can produce holes in the skull and can be confused with trepanation.
17
18 Taphonomic changes, such as root action or bone erosion, should be ruled out, as they cannot
19
20 produce any bone reaction. As for pathological conditions which can mimic a trepanation, bone
21
22 perforations can be produced by congenital defects, trauma, neoplasms, and infectious diseases. In
23
24 general, the produced lesions are irregular in shape, which allow to distinguish them for trepanation.
25
26
27 However, a careful differential diagnosis is necessary (Verano, 2016).

28
29 The trepanations examined in this review have considered a series of criteria, including
30 archaeological context, sex and age distribution, number of trepanations, involved bone, laterality,
31
32 technique of trepanation, description of the lesions, reasons for trepanation, and signs of healing, as
33
34 summarized in Table 1 and 2.

35 36 37 38 39 40 41 **Archaeological context of trepanations**

42
43 There was a great difference among the archaeological contexts in which the Italian trepanned
44
45 individuals were found, both in terms of time and of culture. Not all the findings are well
46
47 documented as the archaeological excavations were carried out several years ago and have been
48
49 published only partially or incompletely. The archeological context of the specimens are reported in
50
51 table 1.

52
53
54 The general trend reveals that no differences have been reported between individuals submitted to
55
56 the practice of trepanation and other skeletons found in the same burial context; the majority of
57
58 trepanned individuals were buried in graves showing the same features as the other burials in the
59
60

1
2
3 necropolis or in the surrounding funerary context. Nevertheless, in rare cases the archaeological
4
5 details may indicate that the trepanned individual should be distinguished from the general
6
7 population, as in the Neolithic case of Grotta Patrizi, where the accuracy of the deposition and the
8
9 richness of the funerary equipment suggest an important role of the subject within the community
10
11 (Radmilli, 1974). However, it should be taken into consideration that some individuals were
12
13 discovered in a disturbed archaeological context; in other cases, little if no information about burial
14
15 customs has been reported, as several archaeological excavations were carried out several decades
16
17 ago, when scarce attention was paid to the taphonomic details. Therefore, it is difficult to evaluate
18
19 whether the trepanned individuals may have played a special role or may have been treated in a
20
21 distinguished manner within their communities.
22
23
24
25
26

27 **Temporal and geographic distribution of trepanations in Italy**

28
29 Trepanation in Italy covers a time span of approximately 7000 years, the most ancient cases being
30
31 dated back to the 5th millennium BC and the most recent example to the 18-19th centuries AD
32
33 (Table 1).
34

35
36 As for the temporal distribution, four cases are attested for the Neolithic period, ranging from the 5th
37
38 to the 4th millennium BC; twelve cases for the Eneolithic, covering the 3rd-2nd millennium; nine
39
40 cases to the Early Bronze Age (first half of the 2nd millennium BC), four to the Bronze Age and
41
42 only one to the Iron Age (8th century). Considering the historical periods, two evidences are dated
43
44 back to the Etruscan Period, six to the Greek or Pre-Roman Age, three to the Roman Age, four to
45
46 the Early Middle Ages, two to the Late Middle Ages, two to the Renaissance, and four to the
47
48 Modern Age. This distribution shows a prevalence of trepanation during prehistoric times, whereas
49
50 some periods are characterized by relatively scarce evidences of this surgical practice, such as the
51
52 Roman and the early and late Middle Ages.
53
54

55
56 As for the geographic distribution of trepanations, the Italian territory can be divided into northern,
57
58 central and southern regions, with a special category represented by the islands (Sardinia and
59
60

1
2
3 Sicily). Eleven cases were discovered in northern Italy (Finale Ligure, Aosta, Lecco, Bologna,
4
5 Alessandria, Cremona, Sabbioneta and Udine), covering the Neolithic, Eneolithic, Bronze Age, Iron
6
7 Age, Early Middle Age, and the Renaissance; twenty cases come from Central Italy (Pescara,
8
9 Cerveteri, Frosinone, Roma, Pisa, Lucca, Grosseto, Vulci, Tarquinia, Cassino, L'Aquila, Latina,
10
11 Livorno and Borgo Cerreto), covering the Neolithic, Eneolithic, Early Bronze, Etruscan, Greek,
12
13 Roman, Late Middle, and Modern Age; eleven cases were found in southern Italy (Matera, Salerno,
14
15 Lecce, Bari, Foggia, Canosa, Otranto), covering the Neolithic period, Greek or Pre-Roman Age,
16
17 Roman Age, Early Middle Age, and Modern Age (fig. 1).
18
19

20
21 The geographic distribution appears to be quite homogeneous, with a prevalence of Central Italy.
22
23 Considering the single regions, Lazio and Tuscany (central Italy) returned the highest number of
24
25 cases, but this incidence can be determined by the large number of archaeological excavations
26
27 carried out in these areas rather than by an effective major diffusion of trepanation. On the contrary,
28
29 some regions show no evidences of trepanation, such as Veneto and Trentino Alto Adige (northern
30
31 Italy), Marche (central Italy), Molise and Calabria (southern Italy), but also in these cases the minor
32
33 archaeological activities could partly explain the absence of evidences.
34
35

36
37 Sardinia is an area particularly rich of evidences, having brought to light nine cases, but all limited
38
39 to the Prehistoric age, starting from the Eneolithic to the Bronze Age. Sicily restituted five
40
41 evidences from Early Bronze Age, Greek age, Early Middle Age, and Modern Age.
42

43
44 The presence of more than one individual with signs of trepanation in the same site is rarely
45
46 documented in the literature and represents the evidence of a diffused practice in a determined
47
48 geographic and chronological context. At this proposal, the three Eneolithic cases from Saint-
49
50 Martin-de Corlèans and the four cases from Grotta dello Scoglietto dated back to the Bronze Age
51
52 are particularly significant, since they document a high concentration of evidences attesting that
53
54 trepanation was a deep-rooted practice in these cultural contexts.
55
56
57

58
59 **Single or multiple?**
60

1
2
3 A total of 88 openings was observed in the 54 individuals. The majority of skulls from Italy present
4 a single trepanation, whereas 12 skulls present multiple holes.
5
6

7 The most ancient case of multiple trepanation is that from Catignano (Canci, 1998) dated back to
8 the Neolithic period and showing two contemporary holes (fig. 2a). Three cases, from
9 Pontecagnano (Salerno) (Petrone et al., 2015), Casamari-Valle del Liri (Germanà & Fornaciari,
10 1992) and Saint-Martin-de-Corlèans (n. TII/71/P17) (Piombino-Mascali et al., 2005; 2006a), go
11 back to the Eneolithic Period and show respectively two holes, probably contemporary, seven holes,
12 some of which incomplete, probably obtained in a unique operation, and two holes, probably
13 obtained in two different surgical interventions. Five cases of multiple trepanations, one from
14 Tuscany and four from Sardinia, are dated to the Bronze Age: Grotta dello Scoglietto 6506, with
15 two perforations practised in different moments (Germanà & Fornaciari, 1992), Su Crucifisu Mannu
16 13, with two contemporary interventions (Germanà & Fornaciari, 1992), Taulera-Alghero, with two
17 holes performed in different moments (Germanà & Fornaciari, 1992), Nuraxi Figus-Gonnesa, with
18 four lesions obtained in at least two different interventions (Germanà & Fornaciari, 1992) (fig. 2b-
19 e), and Seulo, with three holes obtained in two different moments (Germanà & Fornaciari, 1992).
20
21 As for the following periods, a multiple trepanation is attested for the Etruscan-Oscan Age (4th
22 century BC) from Pontecagnano characterized by two holes practised simultaneously (PC 4043)
23 (Fornaciari et al., 1989-90; Germanà & Fornaciari, 1992) and for the Early Middle Ages from
24 Ticineto, with two holes performed in two different moments (Facchini et al., 2003). Finally, the
25 case of Otranto represents a *unicum*, showing 16 trepanations, probably practised on the skull of a
26 martyr in order to obtain bone powder, to be used as an ingredient for pharmacological preparations
27 (Giuffra & Fornaciari, 2015).
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50

51 52 53 54 **Age and sex** 55 56 57 58 59 60

1
2
3 The majority of evidences indicate that trepanation was mainly performed on adult individuals and
4 that this operation was rarely practised on children (Campillo, 1984; 1993; **Andrushko & Verano,**
5 **2008;** Erdal & Erdal, 2011).
6
7
8

9
10 In the Italian specimens this trend is confirmed, as 52 out of 54 trepanned skulls belong to adult
11 individuals, seven of which are young adults or individuals aged between 20 and 25 years; these
12 are the cases from Grotta Patrizi dated back to the Neolithic (Germanà & Fornaciari, 1992), from
13 Pontecagnano dated back to the Eneolithic period (Petrone et al., 2015), from Castenaso dated back
14 to the 8th century BC (Germanà & Fornaciari, 1992), from Imera dated back to 6-5th centuries BC
15 (Fabbri et al., 2005), from Canosa dated back to the 6-7th centuries AD (Facchini et al., 2003), from
16 Ticineto dated back to 5-8th centuries AD (Facchini et al., 2003), and from Monte d'Argento 11B
17 dated back to 11-15th centuries AD (Capasso & Di Tota 1996). The remaining cases are adults aged
18 more than 25 years. However, for the individuals with long-term survival after trepanation, it is
19 impossible to establish the age in which they underwent the operation, whether during childhood or
20 later. In this perspective, worthy of note is the case recorded for a 16-year-old adolescent from
21 Grotta dello Scoglietto (n. 6498), dated back to the Early Bronze Age and, in particular, the case of
22 trepanation attested in a 5/6-year-old child from Fidene, dated back to the Roman Age (Mariani-
23 Costantini et al., 1999, 2000), representing a rare case of intervention practised on a subadult (fig.
24 3).
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42

43 As for the sex of the trepanned individuals, 12 out of 54 cases are females (22.2%), 40 are males
44 (74%) and two are of undetermined sex (3.7%). When analyzing the distribution of sexes in
45 different periods, relevant variations were noticed. In the most ancient period, the Neolithic, the
46 number of cases was equal (two males and two females), whereas a prevalence of males was
47 observed for the Eneolithic (nine males versus two females), the Bronze Age (eleven males versus
48 two females), and the pre-Roman or Greek Age (eight males versus one female), the Roman Age
49 (two males and one female). The Iron Age is represented by a unique male individual, whereas in
50 the Renaissance and Modern Age all the individuals (two and four respectively) were males. Only
51
52
53
54
55
56
57
58
59
60

1
2
3 in the Early and Late Middle Ages there was a preponderance of the female sex (four females
4 versus one male and one undetermined).

5
6
7 As a result, trepanation in Italy was practised prevalently on males, in keeping with the trend
8 attested in other parts of the world (Piek et al., 1999; Roberts & McKinley, 2003; Silva, 2003;
9 Verano, 2003; Andrushko & Verano, 2008; Erdal & Erdal, 2011). This sex ratio could be related to
10 the risks associated to the injuries reported in a warrior episodes or in dangerous working activity,
11 for example hunting, in which only males were engaged.
12
13
14
15
16
17
18
19

20 21 **Localisation of the trepanations**

22
23 Considering the localization of trepanation in the Italian sample, it is evident that the parietals are
24 the most preferred skull bones for trepanation, as 44 out of 88 lesions are located in this region
25 (50%). In decreasing incidence the frontal bone follows with 24 trepanations (27.2%), and the
26 occipital bone with seven lesions (8%). In some cases trepanation was performed on a suture, thus
27 involving two skull bones, i.e. the bregma in five cases (5.7%), the parieto-occipital suture and the
28 fronto-parietal in three cases (3.4%), and temporo-parietal sutures in two cases (2.3%).
29
30
31
32
33
34
35

36 As to the side of trepanation, the majority of lesions are positioned on the left side of the skull, with
37 41 out of 88 lesions (46.6%), whereas 34 (38.6%) are on the right side and 13 (14.8%) are central
38 (fig. 4).
39
40
41

42 Similar preferences for localization and side have been observed in other regions (Roberts &
43 McKinley, 2003; Andrushko & Verano, 2008).
44
45
46
47
48

49 50 **Techniques of trepanation**

51
52 Several techniques of trepanation have been developed over time and space, and mainly include
53 scraping, cutting and drilling. Various combinations of these techniques are also attested.
54
55
56
57

58 59 *Scraping*

1
2
3 Scraping is a primitive but efficacious technique of trepanation that employs an instrument, mainly
4 lithic, with a flat abrasive surface. The technique consists in repeatedly scraping the instrument on
5 the cranial surface until its complete perforation. The obtained lesions generally have an ovoid
6 shape, and are surrounded by a large abrasion ring around the orifice, with external inclination.
7

8
9
10
11 Trepanations by scraping are attested in Italy from the Neolithic until the Modern Age, and 32 out
12 of 54 cases (59.2%) were obtained with this technique, which resulted to be the most commonly
13 used in Italy. For 22 out of 54 cases (40.7%) scraping was the only technique used to obtain a hole.
14
15

16
17
18 The Neolithic and Eneolithic evidences include the cases from Catignano, Arma dell'Aquila, Grotta
19 del Leone, Palombara Sabina, Pianacce-Camaiore, Villeneuve, Specimen B from La Crucca, and
20 the three trepanned skulls from Saint-Martin-de-Corlèans. With regard to the Bronze Age, scraping
21 was used in the skulls from Grotta dello Scoglietto n. 6492 (fig. 5a), Stretto-Partanna, Perdalba-
22 Sardara, Seulo and Paradiso di Laorca. If in prehistoric times trepanation was almost exclusively
23 performed by scraping and with excellent technical skills, its incidence decreased in later historical
24 periods; the technique was observed in the cases from Vulci, Poggiardo, Alba Fucens, Cremona,
25 Monte d'Argento n. 24. Finally, two cases dated back to the Renaissance attest the use of this
26 primitive technique also in these periods: scraping was preferred for the surgical intervention of a
27 historical personage, Vespasiano Gonzaga, and in the skull from Osoppo.
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42

43 *Cutting or sawing*

44
45 The cutting technique consists in using an incisive tool repeatedly on the cranial surface to obtain
46 perforations of various shapes.
47
48

49
50 The practice of incision in Italy is not frequently attested as the unique technique to trepanation: it
51 has been seen in nine out of 54 cases (16.7%). The most ancient example is the Neolithic skull of
52 Trasano; the cases from Grotta dello Scoglietto (fig. 5b) and Sisaia-Dorgali are dated back to the
53 Early Bronze Age. To the historical periods belongs the cases from Pontecagnano PC 990, Gravina,
54
55
56
57
58
59
60

1
2
3 Cassino, Fidene and Alberona (Scattarella et al., 1996). Incision is not attested from the Early
4
5 Middle Ages onwards.

6
7 Other cases demonstrate that the incision was made to widen a perforation obtained through
8
9 scraping (see “Mixed technique” paragraph).
10

11 12 13 14 **Drilling**

15
16 This technique consists in drilling the bone with a sharp and hard stone or with a metallic element
17
18 by exerting pressure and repeatedly drawing and redrawing the groove; as a result, a troncoconical
19
20 hole with circular outline is obtained (Campillo, 2007). Although only a hard sharp stone is
21
22 sufficient to apply this technique, ever since Greek and Roman times two types of drill-bits came
23
24 into use, as reported by Hippocrates in his *De vulneribus capitis* (Vegetti, 1965) and by Celsus in
25
26 his *De medicina liber* (Mazzini, 1999): a standard drill-bit, called *trypanon* by Hippocrates and
27
28 *terebra* by Celsus, and a hollow drill-bit, called *prion* by Hippocrates and *modiolus* by Celsus. Both
29
30 tools leave the same regular cylindrical hole, but the former produced bone powder, the latter a
31
32 bone disc (Germanà & Fornaciari, 1992).
33
34
35

36 In general, drilling is infrequently used in Italy to perform cranial trepanation and only ten out of 54
37
38 cases of drilling as a sole technique are attested (18.5%). The most ancient case of trepanation in
39
40 Italy obtained with drilling seems to be that from Casamari-Valle del Liri, dated back to the
41
42 Eneolithic; however, since one lesion was also produced by scraping, this case is described in the
43
44 paragraph on mixed techniques. The case from Castenaso is debated, since Brasili Gualandi (1980)
45
46 suggested a trepanation performed by scraping but, according to a more recent review, the
47
48 technique should be identified with drilling (Germanà & Fornaciari, 1992). The other cases are from
49
50 Himera, one of them representing the unique evidences of the use of *trypanon* or *terebra* (Fabbri et
51
52 al., 2006), Pontecagnano 4043 (fig. 6a-c), Villa Settibagni in Rome, Canosa, Monte d’Argento 11B
53
54 and Borgo Cerreto,
55
56
57
58
59
60

1
2
3 In the skull from Otranto the 16 holes are the result of a trepanation performed with the use of a
4 particular type of trepan with semi-lunar shaped blade or rounded bit, a tool that could not have
5 produced a bone disc, but only bone powder (Giuffra & Fornaciari, 2015).
6
7
8
9

10 11 *Mixed techniques*

12
13 In 14 out of 54 cases of trepanation scraping was combined with another technique (sawing or
14 drilling), in order to further widen the orifice (25.9%). Scraping and incision was used in the case
15 from Grotta Patrizi, La Crucca A, Su Crucifissu Mannu n.1 (fig. 7), Su Crucifissu Mannu n. 2,
16 Taulera-Alghero, Nuraxi-Figus-Gonnesa, Ticineto, Populonia and Segesta. Drilling and scraping
17 were used in the case from Pontecagnano and Casamari-Valle del Liri. Finally, the combined
18 techniques of drilling and sawing were observed in the specimen 6506 from Grotta dello Scoglietto
19 and in the skull from Monterozzi. Finally, the skull from Comiso reveals a trepanation obtained
20 through incision perfected in the inferior portion with caustication.
21
22
23
24
25
26
27
28
29
30

31
32 As a conclusion, in the Italian sample the most attested technique is scraping (40.7%), followed by
33 drilling (18.5%) and cutting (16.7%); in the remaining cases a mix of techniques was observed. In
34 other regions the techniques showed similar prevalence, such as for example, in the British context,
35 where scraping is the most used (57,7%), followed by drilling (31,9%) and cutting (10,6%) (Roberts
36 & McKinley, 2003). On the contrary, in Anatolia trepanation was obtained prevalently through
37 cutting (37,5%), followed by drilling (32,5%), whereas scraping is the less used technique (12,5%)
38 (Erdal & Erdal, 2011).
39
40
41
42
43
44
45
46
47
48

49 *Bone discs*

50
51 Evidences of cranial discs extracted from the dead, to be worn as amulets, are dated back mainly to
52 prehistoric times and have been discussed by several authors since the late 19th century (Prunières
53 1874; Broca, 1877; Fletcher, 1882; Munro, 1897). The practice is still attested among modern
54 African populations (Merbs, 1989).
55
56
57
58
59
60

1
2
3 In the Italian sample, some exceptional cases of trepanation preserving bone discs are attested. The
4 most ancient is the case from Trasano, dated back to the Neolithic: an ellipsoidal cranial bone
5 fragment that fits with the orifice in the bregmatic area was found in the cranial cavity. This disc
6 was probably obtained during trepanation and was left by the surgeon to cover the orifice during the
7 remaining life of the patient; the disc presents bone resorption on one side, attesting the prolonged
8 contact with the soft tissues that decalcified the bone surface (Germanà & Fornaciari, 1992;
9 Mallegni & Valassina 1996). The case from Sisaia-Dorgali dates back to the Bronze Age, and
10 represents evidence of successful self-transplantation, which consisted in replacing the bone disc in
11 the trepanation hole, followed by resorption of the bone fragment (Germanà & Fornaciari, 1992)
12 (fig. 8a). Another evidence comes from Pontecagnano (PC 990), dated back to the 5-4th centuries
13 BC: in this case, only the posterior half of the bone was left *in situ* (Fornaciari, 2004) (fig. 8b).
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29

30 **Reasons for trepanation**

31 Trepanation was practised by past populations for different reasons, i.e. for therapeutic reasons,
32 ritual purposes and, more rarely, experimental surgery. In the Italian sample it was possible to
33 establish or suppose the reasons for trepanations only in some cases, whereas in others no elements
34 were available to make valid assumptions, so that motives for trepanation necessarily remain
35 speculative or indeterminable.
36
37
38
39
40
41
42
43
44

45 **Healing purposes**

46 Some paleopathological evidences demonstrate that trepanation was used for healing purposes, as it
47 was found in association with various pathologies, especially of traumatic origin (Parker et al., 1986;
48 McKinley, 1992a,b; Germanà & Fornaciari, 1992; Mariani-Costantini et al., 2000; Powers, 2005;
49 Mays, 2006; Weber & Wahl, 2006; Rubini, 2008). In these cases the skull was trepanned to remove
50 bone fragments from cranial fractures. It has also been hypothesized that trepanation was used to
51 treat migraines caused by high intracranial pressure or to cure cerebral disturbances, in particular
52
53
54
55
56
57
58
59
60

1
2
3 those related to vascular pathologies (Facchini et al., 2003). Therefore, it is possible to relate
4
5 trepanation with therapeutic purposes in presence of traumas or other pathologies.
6

7
8 In the Italian sample several trepanations can be related to a trauma treatment. In the Neolithic the
9
10 skull from Catignano exhibits the signs of a healed incomplete fracture of the left fronto-parietal
11
12 region, which could be the cause of the surgical intervention performed to treat or to clean the
13
14 fracture (Germanà & Fornaciari, 1992). The individual from Grotta Patrizi revealed a series of bone
15
16 deformities, such as plagiocephaly, mandible lateralization, 90° rotation of the ulna olecranon and
17
18 other articular dysmorphias, and therefore the trepanation could be related to these anomalies
19
20 (Germanà & Fornaciari, 1992). The two trepanations seen in the Eneolithic case from Pontecagnano
21
22 was probably related to a chronic post-traumatic osteomyelitis (Petrone et al., 2015). The abnormal
23
24 meningeal circulation observed at radiological examination in the individuals from La Crucca A
25
26 and from Taulera-Alghero has been indicated as the cause of a possible persistent migraines, which
27
28 might have induced the surgical interventions (Germanà & Fornaciari, 1992). Traces of a trauma in
29
30 the left parietal can be identified in the skull from Perdalba-Sardara: an erosive lesion with a hole of
31
32 0.6 x 0.4 cm, one on the right parietal, and a circular depression of 2 cm in diameter on the left
33
34 coronal suture; a possible septic-inflammatory reaction due to the trauma could be at the origin of
35
36 the trepanation (Germanà & Fornaciari, 1992). The individual from Pontecagnano 990 presents a
37
38 series of bone traumas, leading to hypothesize an intervention of war surgery: a tendineous lesion is
39
40 visible on the left femur, a blunt force trauma involving only the outer table is detectable on the left
41
42 frontal bone, and therefore the large trepanation was probably carried out to treat a cranial trauma,
43
44 which perhaps damaged the missing portion of the bone left *in situ* (Germanà & Fornaciari, 1992).
45
46
47
48

49
50 The case from Gravina was explained as an intervention performed to treat a penetrating wound
51
52 caused by a pointed weapon, whose penetration point is represented by a lesion 0.4 x 0.2 cm close to
53
54 the trepanation (Sublimi Saponetti et al., 1999). Also the case from Cassino was interpreted as the
55
56 treatment of a probable cranial wound caused by a cutting weapon with a subrectangular section
57
58 that partially penetrated the skull (Rubini, 2008). The margins of the orifice in the skull from Alba
59
60

1
2
3 Fucens preserve the traces of a probable exposed fracture that induced trepanation (Capasso &
4 Capelli, 1995). The child from Fidene represents a particular evidence for trepanation, as the skull
5 shows an abnormal enlarging of the vault, the feature of hydrocephalus; the intervention was thus
6 probably practised to alleviate the intracranial pressure (Mariani-Costantini et al., 2000). Evidences
7 of a dental and vertebral abscess might have caused a meningitis that could explain the trepanation
8 of the female from Villa Settibagni in Rome (Charlier et al., 2006). A lesion continuous with the
9 trepanation observed in the skull from Ticineto is likely to have depended on a previous traumatic
10 event, which was treated with a surgical intervention (Facchini et al., 2003). The therapeutic
11 purpose is evident in the skull from Cremona, as it shows the signs of a frontal fracture produced by
12 a sharp force trauma, responsible for a large abscess on the roof of the left orbit (Lunardini et al.,
13 2000). An endocranial depression interpreted as the result of the compressive action of cerebral
14 neoformation of indeterminable nature is probably at the origin of the trepanation in the case from
15 Monte D'Argento 11B; on the same site, in the case 24 trepanation was performed to treat a fracture
16 of the left parietal whose traces are visible on the outer table (Capasso & Di Tota, 1996). The causes
17 of the trepanation observed in the skull of Vespasiano Gonzaga are revealed by historical sources,
18 which refer that the Duke had been submitted to the operation to treat syphilis; the luetic lesions
19 evident on the cranial surface confirm that the Duke was affected by this infectious disease
20 (Germanà & Fornaciari, 1992) (fig. 9a). Another traumatic lesion produced by a sharp force trauma
21 on the frontal bone is interpreted as the reason for the trepanation in the skull from Osoppo (Ronco,
22 1994). The particularly delicate area of the skull and the shape of the lesion observed in the skull of
23 Populonia has led to suppose an intervention aimed at removing the evidence of an injury
24 (Piombino-Mascoli et al., 2006b). Finally, the small and aligned lesions in the skull from Comiso
25 are probably of traumatic origins, and therefore the trepanation was practised to treat this trauma
26 (Germanà & Fornaciari, 1992).
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

1
2
3 In some cases the Authors hypothesized a trepanation with therapeutic purposes also in absence of
4 bone pathologies, as in the skull from Arma dell'Aquila, in which the uncommon selected area
5 (occipital) has led to suppose the treatment of disturbances of the soft tissues (Canci, 1998).
6
7
8
9

10 11 *Ritual purposes*

12
13
14 Trepanation may have had a ritual significance, especially when practised *post-mortem* (Lisowski,
15 1967). According to Campillo (1984), *post-mortem* trepanations undoubtedly had a ritualistic
16 character, especially in the cases showing multiple openings with no signs of healing.
17
18

19
20 The preference for a particular area of the skull to perform trepanation, i.e. the bregmatic region,
21 has led to suppose a ritual intervention, as in the Neolithic case from Trasano, in which the presence
22 *in situ* of a portion of the bone disc supports this hypothesis (Germanà & Fornaciari, 1992) (fig. 9b).
23
24

25 A ritual purpose has been advocated for three cases discovered at Saint-Martin-de Corlèans, owing
26 to the absence of any signs of pathologies, to the high concentration of trepanation in the same
27 context, and to the strong cultural nature of the site, linked to agricultural and pastoral symbolism
28 (Piombino-Mascoli et al., 2006a). A ritual trepanation performed *post-mortem* cannot be ruled out
29 for the skull from Canosa (Facchini et al., 2003). The most likely hypothesis to explain the multiple
30 trepanations in the skull from Otranto is that the procedure was performed *post-mortem* to obtain
31 bone powder as ingredient for pharmacological preparations. The skull of a martyr is very likely to
32 have been regarded as having medicinal properties, and 17th century prescriptions recommend the
33 use of pulverized bone obtained from individuals who had died a violent death and had not been
34 buried, as is the case of the martyrs of Otranto (Giuffra & Fornaciari, 2015).
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49

50 51 *Experimental surgery*

52
53 An explanation for *post-mortem* trepanation, even if very difficult to demonstrate, is the practice of
54 surgery on cadavers. A number of cases of multiple *post-mortem* trepanations were interpreted as
55 cases of experimental surgery. Campillo (1993: 62, fig. 1) described a skull with seven holes, dated
56
57
58
59
60

1
2
3 back to the 5th century BC from Son Real (Spain), as *post-mortem* trepanation by drilling. Another
4
5 case from Perge (Turkey) and dated to the Roman period shows eight holes in two rows on the right
6
7 half of the frontal bone (Erdal & Erdal, 2011). For these cases the Authors concluded that
8
9 trepanations were aimed at skill training or practise.
10

11
12 In the Italian sample, the only case in which a training purpose has been hypothesized is that of
13
14 Imera. No traumatic lesions could be detected, so a therapeutic intervention was ruled out;
15
16 trepanation was carried out *peri-mortem* or *post-mortem*, as demonstrated by the lack of bone
17
18 reactions; the trepanation was certainly not performed to produce a bone disc, since the instrument
19
20 that was used, a *trypanon*, could produce only bone powder; the conclusions of the authors is that
21
22 training could be a possible explanation (Fabbri et al., 2012). However, the elements in favor of this
23
24 hypothesis are weak, because the cases in the literature interpreted as experimental surgery showed
25
26 multiple perforations; therefore, in our opinion the single hole observed in the skull of Imera cannot
27
28 justify this interpretation and the reasons for the trepanation remain unclear, but a "*peri mortem*"
29
30 surgical trepanation is an easier interpretation.
31
32
33
34
35

36 **Healing of trepanations**

37
38 Paleopathological evidences demonstrate a high percentage of long-term healing associated with
39
40 trepanation (Campillo, 1993; Chege et al., 1996; Stone & Urcid, 2003), even in cases of multiple
41
42 perforations (Genna, 1933-34; Germanà & Fornaciari, 1992). The success of the procedure
43
44 depended on the skill of the surgeon, the occurrence of infection and the possible damage to the
45
46 brain, blood vessels or other structures.
47
48

49
50 Among the 54 cases of trepanation from Italy, 48 (88.8 %) individuals survived the operation. Only
51
52 six patients revealed an absence of healing signs; they included the Eneolithic cases of Villeneuve
53
54 and Saint-Martin-de-Corlèans (n.TII/180/P16), whose trepanations were performed with the
55
56 scraping technique; the two Greek cases from Himera, performed by using the Hippocratic
57
58 trepanon; the early medieval case from Canosa, probably performed with a trepan and the Modern
59
60

1
2
3 case from Otranto, again carried out with a trepanon. Only the latter skull was surely trepanned
4
5 *post-mortem*, whereas for the other cases it is not possible to establish whether they were *intra-*
6
7 *vitam* operations to which the patient did not survive, or were posthumous trepanations. However,
8
9 the majority of cases with absence of healing are those performed with the technique of drilling,
10
11 probably as it was more risky compared to scraping and sawing.
12

13
14 In any case the percentage of interventions with signs of healing is among the highest observed in
15
16 studies on trepanation. Survival in Anatolia was ascertained in 60% of cases (Erdal & Erdal, 2011),
17
18 in pre-Columbian Peruvian Inca skulls 77.5% revealed total or partial healing (Chege et al., 1996),
19
20 in Mexican skulls the prevalence raised to 80% of healing (Stone & Urcid, 2003). The Italian results
21
22 can be compared with the Canadian and USA cases that showed 90% of healing (Stone & Urcid,
23
24 2003).
25

26
27 The majority of cases reveal an evident hyperostotic reaction, partial repair of the perforation, or
28
29 obliteration of the diploic structure, demonstrating long-term survival. The duration of the healing
30
31 period, reported for each case in table 1, was determined by original authors on the basis of the
32
33 grade of reparation and bone reaction around the lesion.
34
35

36 37 38 **Conclusions**

39
40 Analysis of the evidences of trepanation in Italy has demonstrated that it is difficult to determine
41
42 from the archaeological context whether the trepanned individuals may have played a special role or
43
44 may have been treated in a distinguished manner compared to the other individuals buried in the
45
46 same site; the general trend reveals that such a difference is not perceived.
47
48

49
50 A total of 54 individuals from 43 different Italian archaeological sites were found to have evidence
51
52 of trepanation. Trepanation in Italy was diffused in all geographical regions and in all periods,
53
54 ranging from the 5th millennium BC to the 18-19th centuries. The majority of individuals show a
55
56 single trepanation, whereas some skulls present multiple holes. It may also be concluded that
57
58 trepanation was reserved to adult individuals, except for some rare cases, and shows a relevant
59
60

1
2
3 preponderance for the male sex. The most diffused technique in Italy is scraping; cutting and
4
5 drilling are rarely attested, especially as unique techniques to obtain trepanation, whereas they were
6
7 used more frequently in combination with scraping. Only in a minority of cases the reasons of this
8
9 surgical operation can be argued; in these cases, a therapeutic intervention designed to treat a
10
11 traumatic wound or other pathologies is very likely. Only a few evidences of trepanation performed
12
13 as ritual intervention or as experimental surgery are attested, whereas in several cases the reasons
14
15 for trepanation remain unclear or not determinable. A high percentage of long-term healing
16
17 associated with trepanation has been evidenced, with survival of 88.8% of patients.
18
19
20
21
22
23
24
25
26
27
28
29

30 **References**

- 31
32 Andrushko VA, Verano JW. 2008. Prehistoric trepanation in the Cuzco Region of Peru: a view into
33
34 an ancient Andean practice. *American Journal of Physical Anthropology* **37**: 4–13.
35
36 Antonelli V. 1928. Vestigia eneolitiche nella Valle del Liri. *Bullettino di Paletnologia Italiana* **48**:
37
38 169.
39
40 Baggieri G, Di Giacomo M. 2003. New cases of cranial trepanation. In *Trepanation. History,*
41
42 *discovery, theory*, Arnott R, Finger S, CUM Smith (ed). Editors Swets and Zeitlinger publishers:
43
44 Lisse, The Netherlands; 137-145.
45
46 Baggieri G, Di Giacomo M. 2004. A trepanned skull of the Eneolithic Age from Palombara Sabina
47
48 (Rome). *Paleopathology Newsletter* **125**: 9-10.
49
50
51 Bennike P., Ancient trepanations and differential diagnosis: a re-evaluation of skeletal remains from
52
53 Denmark. In *Trepanation: History, Discovery, Theory*, Arnott R Finger S, Smith CUM (eds). Swets
54
55 & Zeitlinger Publications: Lisse, The Netherlands: 96–115.
56
57
58
59
60

- 1
2
3 Brasili Gualandi P. 1980. Note antropologiche su alcuni reperti villanoviani rinvenuti a Castenaso
4 (Bologna). *Seminario di Scienze Antropologiche* **2**: 163-170.
5
6
7 Broca P. 1867. Trépanation chez les Incas. *Bulletins et Mémoires de la Société d'Anthropologie de*
8
9
10 *Paris* **2**: 403–408.
11
12 Broca P. 1877. *Sur la trepanation du crane et les amulettes craniennes à l'époque néolithique.*
13 Ernest Leroux Editeur: Paris.
14
15
16 Businco L. 1933. Scheletri protosardi rinvenuti in recenti scavi in Campidano e Barbagia. *Monitore*
17
18 *Zoologico Italiano suppl.* **44**: 323-326.
19
20
21 Campillo D. 1984. Neurosurgical pathology in prehistory. *Acta Neurochirurgica (Wien)* **70**: 275–
22
23 290.
24
25
26 Campillo D. 1993. *Paleopatologia: Los Primers Vestigios de la Enfermedad.* Fundacion Uriach:
27
28 Barcelona.
29
30
31 Campillo D. 2007. *La Trepanación Prehistórica.* Edicions Bellaterra: Barcelona.
32
33
34 Canci A. 1998. Lesioni del cranio in resti scheletrici umani di epoca neolitica rinvenuti presso
35 l'Arma dell'Aquila (Finale Ligure-Savona). *Bullettino di Paletnologia Italiana* **89**: 81-92.
36
37
38 Capasso L, Capelli A. 1995. A trephined skull from Central Italy (Alba Fucens, Abruzzo), dated to
39 Roman time (I-II century AD). Proceedings of the XXth European Meeting of the Paleopathology
40 Association, Barcelona; pp. 103-106.
41
42
43 Capasso L, Di Tota G. 1995. Tre casi di aperture craniche dalla Necropoli Medievale di Monte
44 d'Argento (Latina, Italia centrale, XI-XV secolo d.C.). *Archivio per l'Antropologia e la Etnologia*
45
46 **CXXV**: 123-140.
47
48
49
50 Capasso L, Di Tota G. 1996. Possible Therapy for Headaches in Ancient Times. *International*
51
52 *Journal of Osteoarcheology* **6**: 316-319.
53
54
55
56 Charlier P, Brun L, Pantano W, Catalano P, Augias A, Huynh-Charlier I. 2014. An incomplete fatal
57 trepanation diagnosed on cremation remains (Rome, Italy, 2nd C. AD). *Acta Medico-Historica*
58
59 *Adriatica* **12**: 315-320.
60

- 1
2
3 Charlier P, Catalano P, Digiannantonio S. 2006. La paléochirurgie ou la naissance de la chirurgie.
4 Une trépanation à Rome à l'époque impériale: un exemple pratique de neurochirurgie antique.
5 *Journal de Chirurgie* **143**: 323-324.
6
7
8
9
10 Chege N, Sartoris DJ, Tyson R, Resnick D. 1996. Imaging evaluation of skull trepanation using
11 radiography and CT. *International Journal of Osteoarchaeology* **6**: 249–2258.
12
13
14 Corrain C. 1986. *I resti scheletrici della necropoli eneolitica di Villeneuve (Aosta)*. Industrie
15 Grafiche ed Musumeci, Aosta.
16
17
18 Crubezy E, Bruzek J, Guilaine J, Cunha E, Rouge´ D, Jelinek J. 2001. The antiquity of cranial
19 surgery in Europe and in the Mediterranean basin. *Earth and Planetary Sciences* **332**: 417– 423.
20
21
22 Di Salvo R, Germanà F. 2002. Dettagli antropologici e paleopatologici in un cranio femminile
23 trapanato dalla necropoli araba di Segesta (Calatafimi-Trapani, Sicilia). *Archivio per l'Antropologia*
24 *e la Etnologia* **CXXXII**: 323-339.
25
26
27
28
29 Erdal YS, Erdal ÖD. 2011. A review of trepanations in Anatolia with new cases. *International*
30 *Journal of Osteoarchaeology* **21**: 505-534.
31
32
33
34 Fabbri PF, Fornaciari G, Caramella D, Accomando G, Vassallo S. 2006b. Discovery of the first
35 Hippocratic cranial trepanation from the Greek colony of Himera, Sicily (6th-5th century B.C.).
36 *Paleopathology Newsletter* **136**: 6-10.
37
38
39
40 Fabbri PF, Lonoce N, Masieri M, Caramella D, Valentino M, Vassallo S. 2012. Partial cranial
41 trephination by means of hippocrates's trapano from 5th century BC Himera (Sicily, Italy).
42 *International Journal of Osteoarchaeology* **22**: 194-200.
43
44
45
46 Fabbri PF, Schettino R, Vassallo S. 2006a. Lo scavo delle sepolture della necropoli di Himera
47 Pestavecchia (Palermo). In *Guerra e pace in Sicilia e nel mediterraneo antico (VIII-III sec. a.C.):*
48 *arti, prassi e teoria della pace e della guerra*. Atti delle Quinte Giornate Internazionali di studi
49 sull'area Elima, Erice, 12-15 ottobre 2003. Ed. della Normale, Seminari e Convegni 7, vol. 2: 613-
50
51
52
53
54
55
56
57
58
59
60

1
2
3 Facchini F, Rastelli E, Ferrero L, Fulcheri E. 2003. Cranial trepanation in two skulls of early
4
5 medieval Italy. *Homo* **53**: 247–254.
6

7 Ferrarese Ceruti ML, Germanà F. 1978. Sisaia, una deposizione in grotta della cultura di
8
9 Bonannaro. *Quaderni della Soprintendenza ai beni Archeologici per le provincie di Sassari e*
10
11 *Nuoro* **6**.
12

13 Ferrarese Ceruti ML. 1972-74. La tomba XVI di su Crocifissu Mannu e la cultura di Bonannaro.
14
15 *Bullettino di Paletnologia Italiana* **81**: 113-210.
16

17 Ferrarese Ceruti ML. 1981. La cultura di Bonannaro, LXVII-LXXVI. In *Ichnussa*. AAVV.
18
19 Scheiwiller: Milano.
20

21 Fletcher R. 1882. *On prehistoric trephining and cranial amulets*. Governement Printing Office:
22
23 Washington.
24

25
26
27 Fornaciari G, Mezzetti MG, Roselli A. 1989-90. Trapanazione cranica del IV secolo a.C. da
28
29 Pontecagnano (Salerno). *Studi etruschi* **56**: 285-86.
30

31 Fornaciari G, Naccarato AG. 1993. La trapanazione del cranio in Italia. In *Le origini della chirurgia*
32
33 *italiana*, Capasso, L. (ed). Ministero per i Beni Culturali e Ambientali: Roma; 67-79.
34

35
36 Fornaciari G. 2004. La Trapanazione del cranio in Età classica: Il Caso di Pontecagnano, Salerno
37
38 (IVsecolo a.C). *Anthropos and Iatria* **7**: 34-40.
39

40 Fornaciari, G. 2002. Medicina greco-romana e paleopatologia. In *La Medicina Greco-Romana:*
41
42 *Scienza e Tecnologia nel mondo greco-romano*, Volterrani E, Fornaciari G. (eds). Felici Editore:
43
44 Pisa; 41-52.
45

46
47 Genna G. 1933-1934. Elementi eneolitici cromagnonoidi nel Lazio. *Rivista di Antropologia* **30**:
48
49 235-262.
50

51 Germanà F, Fornaciari G. 1992. *Trapanazioni, craniotomie e traumi cranici in Italia dalla*
52
53 *preistoria all'età moderna*. Giardini Editori: Pisa.
54
55
56
57
58
59
60

1
2
3 Giuffra V, Fornaciari G. 2015. Pulverized human skull in pharmacological preparations: possible
4 evidence from the "martyrs of Otranto" (southern Italy, 1480). *Journal of Ethnopharmacology* **160**:
5
6 133-139
7

8
9
10 Holck P. 2008. Two medieval 'trepanations': therapy or swindle? *International Journal of*
11
12 *Osteoarchaeology* **18**: 188–194.
13

14 Jennbert K. 1991. Trepanation from Stone Age to medieval period from a Scandinavian perspective.
15
16 In *Regions and reflections*. In Honour of Marta Stromberg, Jennbert K, Larsson L, Petré R,
17
18 Wysomirska-WERbart B (eds). Almqvist and Wiksell: Lund; 357-378.
19

20 Lisowski FP. 1967. Prehistoric and early prehistoric trepanation. In *Diseases in Antiquity*,
21
22 Brothwell DR, Sandison AT (eds). CC Thomas: Springfield; 651–672.
23

24 López B, Caro L, Pardiñas A. 2011. Evidence of trepanations in a medieval population (13th–14th
25
26 century) of northern Spain (Gormaz, Soria). *Anthropological Science* **119**: 247–257.
27

28
29 Lunardini A, Costantini Biasini L, Costantini L, Fornaciari G. 2010. A XVII century skull
30
31 trepanation from Umbria (central Italy). *Journal of Paleopathology* **22**: 51-57.
32

33
34 Lunardini A., Caramella D., Mallegni F., Fornaciari G. 2000. Frontal fracture with therapeutic
35
36 trepanation in an early medieval skull from northern Italy. *Journal of Paleopathology* **12**: 21-25.
37

38 Mallegni F, Valassina A. 1996. Secondary Bone Changes to a Cranium Trepanation in a Neolithic
39
40 Man Discovered at Trasano, South Italy. *International Journal of Osteoachaeology* **6**: 506- 511.
41

42 Mallegni F. 1981. Analisi antropologica e paleopatologica degli inumati di Poggiardo. *Studi di*
43
44 *Antichità* **2**: 175-196.
45

46
47 Margetts E. 1967. Trepanation of the skull by the medicine-men of primitive cultures, with
48
49 particular reference to present-day native East African practice. In *Diseases in Antiquity*, Brothwell
50
51 D, Sandison AT (eds). Charles C. Thomas: Springfield, IL; 673–701.
52

53
54 Mariani-Costantini R, Catalano P, di Gennaro F, di Tota G, Angeletti RT. 2000. New light on
55
56 cranial surgery in ancient Rome. *The Lancet* **355**: 305–307.
57
58
59
60

- 1
2
3 Mariani-Costantini R., Di Tota G, Catalano P, Ottini L, Angeletti LR. 1999. Cranial trepanation in
4 Greco-Roman medicine. *Journal of Paleopathology* **11**: 5-11.
5
6
7 Mays S. 2006. A possible case of surgical treatment of cranial blunt force injury from Medieval
8 England. *International Journal of Osteoarchaeology* **16**: 95–103.
9
10
11
12 Mazzini I. 1999. *La chirurgia. Libri 7- e 8- del De medicina di Celso Aulo Cornelio*. Istituti
13 Editoriali e Poligrafici: Macerata.
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
- Mazzucchi A, Gaudio D, Galassi A, Cattaneo C. 2009. The study of cranial trauma in ancient populations: trepanation to therapy in four cases from northern Italy. XXI Congress of the International Academy of Legal Medicine, Poster session, Lisbon. Available at:<[http.handle.net/2434/166917](http://handle.net/2434/166917)>.
- McKinley JI. 1992a. A probable trepanation from an early Anglo-Saxon cemetery at Oxborough, Norfolk. *International Journal of Osteoarchaeology* **2**: 333–335.
- McKinley JI. 1992b. A skull wound and possible trepanation from a Roman cemetery at Baldock, Hertfordshire. *International Journal of Osteoarchaeology* **2**: 337–340.
- Merbs CF. 1989. Trauma. In *Reconstructing of life from the skeleton*, Iscan MY, Kennedy KAR (eds). AR Liss: New York; 161-189.
- Munro R. 1897. *Prehistoric Problems*. William Blackwood and Sons: Edinburgh.
- Novak SA, Knüsel CJ. 1997. Comment on Mallegni and Valassina's secondary bone changes to a cranium trepanation in a neolithic man discovered at Trasano, South Italy. *International Journal of Osteoarchaeology* **7**: 555–557.
- Pardini E, Innocenti F, Fulgaro A, Rossi V, Stefania G, Patara S. 1982. Gli inumati di Pontecagnano (Salerno). *Archivio per l'Antropologia e la Etnologia* **112**: 281-327.
- Parenti R, Vanni V, Convalle R. 1960. Studio antropologico dei resti scheletrici rinvenuti nella Grotta del leone di Agnano (Pisa). *Archivio per l'Antropologia e la Etnologia* **90**: 129-211.
- Parenti R. 1962. Antropologia dei resti scheletrici dello Scoglietto (Età del Bronzo). *Archivio per L'Antropologia e la Etnologia* **92**: 7-103.

- 1
2
3 Parker S, Roberts C, Manchester K. 1986. A review of British trepanations with reports on two new
4 cases. *Ossa* **12**: 141–157.
5
6
7 Patrizi S, Radmilli AM, Mangili G. 1950. Sepoltura ad inumazione con cranio trapanato nella
8 Grotta Patrizi, Sasso-Furbara. *Rivista di Antropologia* **41**: 3-68.
9
10
11 Petrone P, Niola M, Di Lorenzo P, Paternoster M, Graziano V, Quaremba G, Buccelli C. 2015.
12 Early medical skull surgery for treatment of post-traumatic osteomyelitis 5,000 years ago. *PLoS*
13 *One* **10**(5):e0124790.
14
15
16
17
18 Piek J, Lidke G, Terberger T, Von Smekal U, Gaab MR. 1999. Stone Age skull surgery in
19 Mecklenburg-Vorpommern: a systematic study. *Neurosurgery* **45**: 147–151.
20
21
22
23 Piggott A. 1940. A trepanned skull of the Beaker period from Dorset and the practice of trepanning
24 in prehistoric Europe. *Proc Prehist Soc* **6**: 112–32.
25
26
27
28 Piombino Mascali D, Mallegni F, Fornaciari G, Bartoli F. 2005. Trepanation in prehistoric Italy:
29 three cases from Saint-Martin-de- Corléans (Aosta). Abstract 1st Paleopathology Association
30 Meeting in South America-PAMinSA, Rio de Janeiro, 27-29 July 2005.
31
32
33
34 Piombino Mascali D., Bartoli F, Mallegni F., Fornaciari G. 2006a. I crani trapanati preistorici di
35 Saint-Martin-de-Corléans (2300-1900 a.C.). In *Preistoria dell'Italia settentrionale. Studi in ricordo*
36 *di Bernardino Bagolini*,. Pessina A, Visentini P (a cura di). Atti del Convegno Udine settembre
37 2005; 555-562.
38
39
40
41
42
43 Piombino-Mascali D, Bartoli F, Pagni G, Fornaciari G, Mallegni F. 2006b. A Late Renaissance case
44 of trepanation and pseudopathological damage from Populonia (central Italy). *Journal of*
45 *Paleopathology* **18**: 15-20.
46
47
48
49 Prunières PB. 1874. Sur les crânes perforés et les rondelles crâniennes de l'époque néolithique.
50 *Compte Rendu de l'Association Française pour l'Avancement des Sciences* **3**: 597– 635.
51
52
53
54 Puccioni N. 1915. Esplorazione di alcune grotte della Versilia (grotticelle sepolcrali delle Pianacce).
55 *Archivio per l'Antropologia e la Etnologia* **45**: 27-63.
56
57
58
59
60

- 1
2
3 Radmilli AM. 1974. Dal Paleolitico all'Età del Bronzo. In *Popoli e civiltà dell'Italia Antica*.
4
5 AAVV. Biblioteca di Storia Patria: Roma; 69-536.
6
7 Robb JE, Mallegni F. 1994. Anthropology and paleopathology of Neolithic human remains from
8
9 Catignano (Pescara, Italy). *Rivista di Antropologia* **72**: 197–224.
10
11 Roberts C, McKinley J. 2003. Review of trepanations in British antiquity focusing on funerary
12
13 context to explain their occurrence. In *Trepanation: History, Discovery, Theory*. Arnott R, Finger S,
14
15 Smith CUM (eds). Swets & Zeitlinger Publications: Lisse, The Netherlands; 55–78.
16
17 Roberts C, McKinley J. 2003. Trepanation in the Portuguese Late Neolithic, Chalcolithic and Early
18
19 Bronze Age periods. In *Trepanation: History, Discovery, Theory*, Arnott R Finger S, Smith CUM
20
21 (eds). Swets & Zeitlinger Publications: Lisse, The Netherlands: 55–78.
22
23 Ronco D. 1990. Un campione di popolazione dell'età del Bronzo di Paradiso di Laorca (Lecco):
24
25 paleobiologia. In *Carta archeologica della Lombardia, IV: la provincia di Lecco*. Casini S. (ed).:
26
27 Musei civici: Lecco; 81-90.
28
29 Ronco D. 1994. Un calvario trapanato di epoca rinascimentale proveniente dalla chiesa di S. Pietro
30
31 a Osoppo (UD). *Quaderni Friulani di Archeologia* **IV**: 7-10.
32
33 Rubini M. 2008. A case of cranial trepanation in a Roman necropolis (Cassino, Italy, 3rd century
34
35 BC). *International Journal of Osteoarchaeology* **18**: 95-99.
36
37 Rytel MM. 1956. Trephinations in ancient Peru. *Quarterly Bulletin of Northwestern University*
38
39 *Medical School* **30**: 365–3369.
40
41 Scattarella V, Sublimi Saponetti S, Cuscianna N, Gattuli A. 1996. A case of skull trephination from
42
43 late Imperial Rome. *Journal of Paleopathology* **8**: pp.85-88.
44
45 Silva AM. 2003. Trepanation in the Portuguese late Neolithic and early Bronze Age period. In
46
47 *Trepanation: History, Discovery, Theory*. Arnott R, Finger S, Smith CUM (eds). Swets & Zeitlinger
48
49 Publications: Lisse, The Netherlands; 117–130.
50
51 Stewart TD. 1958. Stone Age skull surgery: a general review, with emphasis on the New World.
52
53 *Annual Report Smithsonian Institution*: 469–491.
54
55
56
57
58
59
60

1
2
3 Stone JL, Urcid J. 2003. Pre-Columbian skull trepanation in North America. In *Trepanation: History, Discovery, Theory*, Arnott R Finger S, Smith CUM (eds). Swets & Zeitlinger Publications:
4
5
6
7 Lisse, The Netherlands; 237–249.

8
9
10 Sublimi Saponetti S, Scattarella V, Laraspata, Selvaggi A. 1999. Cranial trepanation in an
11 individual of the Hellenistic age (III century BC) from the necropolis of Contrada Santo Stefano
12 (Gravina-Bari, Italy). *Atti del XIII Congresso A.A.I. Roma-Sabaudia*, ottobre 1999; 123-127.

13
14
15
16 Sublimi Saponetti S, Scattarella V, Volpe G. 1998. Cranial trepanation in an individual of the
17 Hellenistic Age (III century BC) from the necropolis of contrada S. Stefano (Gravina-Bari, Italy).
18
19
20
21
22 *Journal of Paleopathology* **10**: 119-123.

23
24
25 Tozzi C. 1978. Un aspetto della corrente culturale della ceramica dipinta in Abruzzo. Il villaggio di
26 Catignano (Pescara). *Quaderni de la Ricerca Scientifica* **100**: 95-111.

27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
Vegetti M. 1965. *Ippocrate, opere*. UTET: Torino.

Verano J. 2003. Trepanation in prehistoric South America: geographic and temporal trends over
2000 years. In *Trepanation: History, Discovery, Theory*, Arnott R Finger S, Smith CUM (eds).
Swets & Zeitlinger Publications: Lisse, The Netherlands; 223–236.

Verano J. 2016. Differential diagnosis: trepanation. *International Journal of Paleopathology* **14** : 1-
9.

Weber J, Wahl J. 2006. Neurosurgical aspects of trepanations from Neolithic times. *International
Journal of Osteoarchaeology* **16**: 536–5545.

Weber J. and Wahl J. 2006. Neurosurgical aspects of trepanations from Neolithic times.
International Journal of Osteoarchaeology **16**: 536–545.

Zanello M, Decofour M, Corns R, Pallud J, Charlier P. 2015. Report of a successful human
trepanation from the Dark Ages of neurosurgery in Europe. *Acta Neurochirurgica (Wien)* **157**: 303-
4.

Legend to figures

Figure 1 Map of Italy with the archaeological sites cited in the text

Figure 2 Trepanation from Catignano (Neolithic period, old adult female), showing two contemporary holes (a); trepanation in the skull of Nuraxi Figus-Gonnesa (Bronze Age, middle-aged adult male) (b), with 4 lesions obtained in at least two different interventions (c-e)

Figure 3 Trepanation from Fidene (2nd century AD) practised on a child of 5-6 years of age (a); detail of the lesion (b) and radiological examination showing evidences of hydrocephalus (c)

Figure 4 The approximate location of all lesions found on 53 skulls; the lesions on the skull from Otranto have not been represented

Figure 5 Trepanation from Scoglietto 6492 (Early Bronze Age, adult male) with an ellipsoidal depression and a central hole obtained through scraping (a); trepanation from Scoglietto 6511 (Early Bronze Age, 25-20 year-old-male) obtained by the technique of incision, which produced a lanceolate depression with no perforation, owing to the complete reparation of the orifice (b)

Figure 6 Trepanation from Pontecagnano 4043 (4th century BC, adult male) (a) with two contemporary trepanations obtained by drilling (b) and radiological examination (c)

Figure 7 Trepanation from Su Crucifissu Mannu 1 (Early Bronze Age, 20-30 year-old-male) (a), showing a rhomboid depression obtained through scraping and a central rounded perforation probably opened and widened through incision (b)

Figure 8 Trepanation from Sisaia Dorgali (Bronze Age, adult female) with the bone disc replaced in the trepanation hole, followed by resorption of the fragment (a); trepanation from Pontecagnano 990 (5-4th centuries BC, 40-45 year-old-male) with implantation of one half of the bone disc (b)

Figure 9 Trepanation of Vespasiano Gonzaga (1531-1591), performed to treat venereal syphilis, as attested by historical sources and by the luetic lesions visible on the skull surface (a); trepanation from Trasano (Neolithic) with the bone disc *in situ*, leading to suppose a ritual purpose for the surgical intervention (b)

	Site	Period	Archaeological context	Sex and age	Reasons	Healing	References
1	Catignano (Pescara)	Neolithic (V millennium BC)	Grave pits within villages	F, old adult	Trauma	P (1 year)	Tozzi, 1978; Germanà & Fornaciari, 1992; Robb & Mallegni 1994
2	Arma dell'Aquila (Finale Ligure)	Neolithic (V millennium BC)	Simple grave pit excavated in cave with 8 individuals	F, 50-60 years	Treatment (?)	P (long)	Parenti et al., 1962; Germanà & Fornaciari, 1992; Canci, 1998
3	Grotta Patrizi (Cerveteri)	Neolithic (end V-beginning IV millennium BC)	Simple grave pit excavated in cave with 4 individuals	M, 20-25	Treatment	P (some months)	Patrizi et al., 1950; Germanà & Fornaciari, 1992
4	Trasano (Matera)	Neolithic (end of V millennium BC)	Grave pits within villages	M, adult	Ritual (to obtain bone disc) (?)	P (several months/one year)	Germanà & Fornaciari, 1992; Mallegni & Valassina, 1996; Novak & Knusel, 1997
5	Pontecagnano (Salerno)	Eneolithic (first half of III millennium BC)	Grave pit leading to a cave shaped funerary chamber with 3 other individuals	M, young adult	Treatment	P (long)	Petrone et al., 2015
6	Casamari-Valle del Liri (Frosinone)	Eneolithic (second half of III millennium BC)	Multiple grave with seven individuals (all males)	M, adult-mature	ND	P (several months/one year)	Antonelli, 1928; Genna, 1930-32; Battaglia, 1954-55; Germanà & Fornaciari, 1992
7	Palombara Sabina (Roma)	Eneolithic (3500-2500 BC)	Single coffin grave	M, 55-65 years	ND	P (ND)	Baggieri & Di Giacomo 2004
8	Grotta del Leone di Agnano (Pisa)	Eneolithic (end of III millennium BC)	Cave with several individuals not in anatomical connection	F?, adult	ND	P (several months/one year)	Battaglia, 1954-55; Parenti et al., 1960; Fornaciari, 1985; Germanà & Fornaciari, 1992
9	Pianacce-Camaiole (Lucca)	Eneolithic (end of III millennium BC)	Cave with several individuals not in anatomical connection	M, old adult	ND	P (more than 1 year)	Puccioni, 1915; Messeri, 1957; Fornaciari, 1985; Germanà & Fornaciari, 1992
10	Villeneuve (Aosta)	Eneolithic	Necropolis	F, adult	ND	A	Corrain, 1986; Germanà & Fornaciari, 1992
11	La Crucca (Sassari), n. A	Eneolithic (half of III-beginning of II millennium BC)	Pre-Nuragic hypogeic tomb	M, old adult	Treatment	P (long survival for the first two moments; a few weeks for the third)	Germanà, 1984; Germanà & Fornaciari, 1986; Germanà & Fornaciari, 1992
12	La Crucca	Eneolithic (half of III-	Pre-Nuragic hypogeic tomb	M, old adult	ND	P	Germanà & Fornaciari, 1992

	(Sassari), n. B	beginning of II millennium BC)				(several years)	
13	Saint-Martin-de-Corlèans (Aosta), n. TII/180/P16	Eneolithic - beginning of Bronze Age (2300-1900 BC)	Multiple megalithic tomb with 16 individuals	M, more than 50 years	Ritual (?)	A	Piombino-Mascali et al., 2006
14	Saint-Martin-de-Corlèans (Aosta), n. TII/71/P17	Eneolithic - beginning of Bronze Age (2300-1900 BC)	Multiple megalithic tomb with 16 individuals	M, 45-55 years	Ritual (?)	P (some months)	Piombino-Mascali et al., 2006
15	Saint-Martin-de-Corlèans (Aosta), n. TII/2/P8	Eneolithic - beginning of Bronze Age (2300-1900 BC)	Multiple megalithic tomb with 16 individuals	M, 35-40 years	Ritual (?)	P (long)	Piombino-Mascali et al., 2006
16	Grotta dello Scoglietto (Grosseto), n. 6492	Early Bronze Age (first half of II millennium BC)	Cave with fragmentary and mixed human remains belonging to at least 42 individuals of both sexes	M, adult (35 years)	ND	P (more than 1 year)	Messeri, 1957; Parenti, 1962; Germanà & Fornaciari, 1992
17	Grotta dello Scoglietto (Grosseto), n. 6498	Early Bronze Age (first half of II millennium BC)	Cave with fragmentary and mixed human remains belonging to at least 42 individuals of both sexes	M, adolescent (16 years)	ND	P (several years)	Messeri, 1957; Parenti, 1962; Germanà & Fornaciari, 1992
18	Grotta dello Scoglietto (Grosseto), n. 6511	Early Bronze Age (first half of II millennium BC)	Cave with fragmentary and mixed human remains belonging to at least 42 individuals of both sexes	M, 25-30 years	ND	P (several years)	Messeri, 1957; Parenti, 1962; Germanà & Fornaciari, 1992
19	Grotta dello Scoglietto (Grosseto), n. 6506	Early Bronze Age (first half of II millennium BC)	Cave with fragmentary and mixed human remains belonging to at least 42 individuals of both sexes	M, adult (30 years)	ND	P (only lesion A, several months)	Battaglia, 1955; Messeri, 1957; Parenti, 1962; Germanà & Fornaciari, 1992
20	Stretto-Partanna (Trapani)	Early Bronze Age (first half of II millennium BC)	Cave tomb with the remains of at least 6 individuals	M, adult	ND	P (ND)	Germanà & Di Salvo, 1991; Germanà & Fornaciari, 1992
21	Su Crucifissu Mannu (Sassari), n. 1	Early Bronze Age	Hypogeic tomb with 20 individuals	M, 20-30 years	ND	P (several months; a few days after the second intervention)	Ferrarese Ceruti, 1972-74; Ferrarese Ceruti, 1981; Germanà, 1971; Germanà & Fornaciari, 1992
22	Su Crucifissu Mannu (Sassari),	Early Bronze Age	Hypogeic tomb with 20 individuals	M, adult	ND	P (few weeks/on	Ferrarese Ceruti, 1972-74; Ferrarese Ceruti, 1981; Germanà, 1972-74;

	n. 13					e month)	Germanà & Fornaciari, 1992
23	Taulera-Alghero (Sassari)	Early Bronze Age	Hypogeic tomb with ca 13 individuals	M, adult	Treatment	P (1 year)	Ferrarese Ceruti & Germanà, 1978; Ferrarese Ceruti, 1981; Germanà, 1971; Germanà & Fornaciari, 1992
24	Perdalba-Sardara (Cagliari)	Early Bronze Age	Arenary cave with the remains of 10 individuals	M	Treatment	P	Ferrarese Ceruti, 1981; Maxia, 1951-52; Germanà & Fornaciari, 1992
25	Nuraxi Figus-Gonnesa (Cagliari)	Bronze Age	Hypogeic tombs	M, middle-old adult	ND	P (lesions A, B, C and D: 1 year. Lesion C was repeated with no survival)	Ferrarese Ceruti, 1981; Germanà, 1987; Germanà & Fornaciari, 1992
26	Seulo (Cagliari)	Bronze Age	Caves limited by dry stone walls	M, old adult	ND	P (2 lesions: several months; the third: ca one-week)	Businco, 1933; Maxia, 1951-52; Germanà & Fornaciari, 1992
27	Sisaia-Dorgali (Nuoro)	Bronze Age	Natural cave	F, adult	ND	P (several months/one year)	Ferrarese-Ceruti & Germanà, 1978; Ferrarese Ceruti, 1981; Germanà & Fornaciari, 1992
28	Paradiso di Laorca (Lecco)	Bronze Age (1495±90 BC)	Rock shelter with the remains of at least 11 individuals	F, adult (30 years)	ND	P (ND)	Ronco, 1990
29	Castenaso (Bologna)	Iron Age (8th century)	Grave tomb containing the remains of three individuals referable to the Villanovian culture	M, 21-25 years	ND	P (several months)	Brasili Gualandi, 1980; Germanà & Fornaciari, 1992
30	Vulci (Viterbo)	Etruscan Age (second half of 6th century BC)	Etruscan necropolis	M, 25-35 years	ND	P (1 year)	Baggieri & Di Giacomo, 2003
31	Monterozzi (Tarquinia)	Etruscan Age (6th century BC)	Etruscan necropolis	M, 35-45 years)	ND	P (few weeks/one month)	Baggieri & Di Giacomo, 2003

32	Imera (Palermo)	6-5th century BC	Eastern necropolis that include 2400 burials	F, 19-20 years	ND	A	Fabbri et al., 2005
33	Imera (Palermo)	5th century BC	Western necropolis that include 5000 burials	M, adult	ND	A	Fabbri et al., 2012
34	Pontecagnano (Salerno), PC 990	5-4th century BC	Pre-roman necropolis	M, 40-45 years	Trauma	P (long)	Pardini et al., 1982; Fornaciari et al., 1989-90; Germanà & Fornaciari, 1992; Pietrangelo et al., 1995; Fornaciari, 2002; Fornaciari, 2004
35	Pontecagnano (Salerno), PC 4043	4th century BC	Pre-roman necropolis	M, adult (30 years)	ND	P (1 year)	Pardini et al., 1982; Fornaciari et al., 1989-90; Germanà & Fornaciari, 1992;
36	Poggiardo (Lecce)	4-3rd century BC	Necropolis with ca 25 burials	M, adult (40 years)	ND	P (long)	Mallegni, 1981; Germanà, 1986; Germanà & Fornaciari, 1992
37	Contrada Santo Stefano, Gravina (Bari)	3rd century BC	Rich chambered tomb at the necropolis	M, 45-50 years	Trauma	P (more than 1 year)	Sublimi Saponetti et al., 1999
38	Cassino	3rd century BC	Necropolis	M, mature adult	Trauma	P (long)	Rubini, 2008
39	Alba Fucens (L'Aquila)	Roman Age (1st-2nd century AD)	Necropolis	M, 40-50 years	Trauma	P (several years)	Capasso & Capelli, 1995
40	Fidene (Roma)	Roman Age (2nd century AD)	Necropolis, which was probably part of a villa in suburban Rome	5-6 years	Treatment	P (few weeks/one month)	Mariani-Costantini et al., 2000
41	Rome (Villa Settibagni)	1st-3rd century AD	Villa on the suburb of Rome	F, adult	Treatment	P (some months)	Charlier et al., 2006
42	Alberona (Foggia)	3rd-4th century AD	Main church; the remains are attributed to St. Vitale, a martyr who lived between 3 rd and 4 th centuries AD	M, adult (40 years)	ND	P	Sublimi Saponetti et al., 1996; Scattarella et al., 1996
43	Canosa (Puglia)	6-7th century AD	Documentation not certain	F, young adult	Ritual (?)	A	Facchini et al., 2003
44	Ticineto (Alessandria)	Late 5th-8th century AD	Multiple grave of the necropolis	ND, young adult	Trauma	P (ND)	Facchini et al., 2003
45	Cremona	7-11th centuries AD	Under the Bell Tower of the Cathedral, coming from a preexisting cemetery dated back to 7 th -12 th centuries	M, 40-50 years	Trauma	P (long)	Lunardini et al., 2000
46	Segesta (Trapani)	10-11th centuries AD	Muslim necropolis of the city dated back to the 10-11 th	F, 25-30 years	ND	P (few weeks/on	Di Salvo & Germanà, 2002

			centuries and containing 62 grave pits buried with Muslim ritual			e month)	
47	Monte D'Argento (Latina), n. 11B	11-15th centuries AD	Necropolis around the church	F?, young adult	Treatment	P	Capasso & Di Tota, 1996
48	Monte D'Argento (Latina), n. 24	11-15th centuries AD	Necropolis around the church	F, adult (30-35 years)	Trauma	P (long)	Capasso & Di Tota, 1996
49	Sabbioneta (Vespasiano Gonzaga)	1531-1591	Buried in the church of Incoronata	M, 59 years	Treatment	P (13 years)	Mallegni et al., 1991; Germanà & Fornaciari, 1992
50	Osoppo (Udine)	Renaissance	Secondary burial under the floor of the church of St. Pietro	M, adult (40 years)	Trauma	P (long)	Ronco, 1994
51	Otranto (Lecce)	15-18 th century	From the Martyrs Chapel in the Cathedral, containing the skeletal remains of hundreds of inhabitants of Otranto killed by the Ottomans in 1480	M, adult	Ritual	A	Giuffra & Fornaciari, 2014
52	Populonia (Livorno)	Second half of 16th century AD	Familiar tomb under the floor of the Chapel of San Cerbone, which contains the remains of at least thirty individuals in a secondary burial dated back to the second half of 16 th century	M, 40-45 years	Trauma (?)	P (several years)	Piombino-Mascali et al., 2006
53	Borgo Cerreto (Perugia)	17 th century	Crypt of the church of The Saints Jesus and Mary in Borgo Cerreto, in use during the 17 th century, in which 8 mummified bodies and other 2 isolated skulls were found	M, 30-35 years	ND	P (long)	Lunardini et al., 2010
54	Comiso (Ragusa)	18-19 th century	Funerary chapel of the S. Maria della Grazia	M, adult	Trauma	P (long)	Germanà & Fornaciari, 1989; Germanà & Fornaciari, 1992

Table 1. Summary of the cases of trepanation from Italy (dating, sex, age at death, reasons, healing and references)

Legend: M = male; F = female; ND = not determinable; A = absent; P = present

For Peer Review

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49

	Site	N. of trepanations	Bone	Side	Technique	Description	Timing	Bone disc
1	Catignano (Pescara)	2	Parietals	C, L	Scraping	1) Irregular, ellipsoidal and crateriform depression of 6.5 x 3.5 cm 2) Oval depression of 3 x 2 cm with a central irregular orifice	Contemporary	-
2	Arma dell'Aquila (Finale Ligure)	1	Occipital	L	Scraping	Circular 4 x 4.7 cm depression, which does not reach the inner surface	-	-
3	Grotta Patrizi (Cerveteri)	1	Near bregma	C	Scraping and sawing	Ellipsoid lesion of 5 x 3 cm; at a later time the operator intervened with a series of incisions along the margin of the orifice, but the patient died soon later	-	-
4	Trasano (Matera)	1	Near bregma	C	Sawing	Ellipsoidal defect of 2.6 x 2 cm		P
5	Pontecagnano (Salerno)	2	Fronto-parietal Parietal close to lambda	L R	1) Scraping 2) drilling	1) ellipsoid depression of 4.9 x 3.9 cm with a central opening of 0.59 x 0.5 cm 2) conical round depression of 0.49 x 0.58 cm without complete perforation	Contemporary	-
6	Casamari-Valle del Liri (Frosinone)	7	Frontal, parietals	C, R, L	Drilling and scraping	1) Lesion A is a crateriform depressed area of 4 x 3 cm with a central ellipsoid orifice; 2) lesion B is a depressed area of irregular rhomboid shape measuring 3 x 2.5 cm with a central hole of 1.4 x 0.7 cm; 3) lesion C is a rounded depressed area of 2.2 x 2.5 cm with a small central elongated hole. 4-7) 4 superficial rounded impressions are also present. Only lesion B was produced by scraping	Contemporary	-
7	Palombara Sabina (Roma)	1	Frontal	L	Scraping	Elliptic depression of 3.4 x 2.3 cm with a little hole of 0.9 x 0.8 cm in size	-	-

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49

8	Grotta del Leone di Agnano (Pisa)	1	Parietal	L	Scraping	Irregularly rhomboid depression whose sides measure 5.5, 2.8, 4.5 and 3.8 cm, with a 4 x 2 cm opening	-	-
9	Pianacce-Camaiole (Lucca)	1	Parietal	C	Scraping	Ellipsoidal depression with a little hole of 0.25 x 0.1 cm was	-	-
10	Villeneuve (Aosta)	1	Parietal	L	Scraping	Irregularly ovoid orifice, whose dimensions are not reported	-	-
11	La Crucca (Sassari), n. A	1	Frontal	R	Scraping and sawing	Unique rounded depression of 2.5 cm in diameter, with a central hole of 2.5 x 1.9 cm; the surface of the skull was initially scraped until reaching a little perforation, then the superior-external portion of the orifice was obtained by sawing, and finally the inferior-medial portion of the hole again through sawing	Three different moments	-
12	La Crucca (Sassari), n. B	1	Occipital	R	Scraping	Ovoid depression of 5.3 x 3.5 cm, with a 1 x 0.7 cm hole in the center	-	-
13	Saint-Martin-de-Corlèans (Aosta), n. TII/180/P16	1	Parietal	R	Scraping	Ellipsoidal hole of 5.8 x 5.2 cm	-	-
14	Saint-Martin-de-Corlèans (Aosta), n. TII/71/P17	2	parietals	L, R	Scraping	1) Depression of 5.5 cm in diameter with a hole of 2.6 x 1.3 cm 2) a depression 4.5 x 4 cm with a hole of 3 x 2.4 cm	Contemporary	-
15	Saint-Martin-de-Corlèans (Aosta), n. TII/2/P8	1	Frontal	R	Scraping	Ellipsoidal hole of 5.7 x 2.8 cm	-	-
16	Grotta dello Scoglietto (Grosseto), n. 6492	1	Bregma	C	Scraping	Ellipsoidal depression of 9.3 x 4.5 cm with a central hole of 2.2 x 1.4 cm	-	-
17	Grotta dello Scoglietto (Grosseto), n.	1	Frontal	L	Sawing	Lanceolate depression of 4.7 x 3.1 cm with a central hole of 0.6 x 0.3 cm; the borders are obliterated by the reparative process	-	-

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49

	6498								
18	Grotta dello Scoglietto (Grosseto), n. 6511	1	Frontal	R	Sawing	Lanceolate depression of 7 x 4.3 cm with no resulting perforation owing to the complete reparation of the orifice	-	-	
19	Grotta dello Scoglietto (Grosseto), n. 6506	2	Parietals	L, R	Scraping and drilling	1) Lesion A, on the right parietal, is an oval depressed area of 5.4 x 3.8 cm with a central rounded orifice of 2.5 cm in diameter obtained through scraping 2) lesion B on the left parietal is an orifice probably produced <i>perimortem</i> with drilling	Two different moments	-	
20	Stretto-Partanna (Trapani)	1	Parietal	R	Scraping	Large 9.2 x 7.5 cm ovoid depression degrading in a central triangular orifice of 7.2 x 5.9 cm	-	-	
21	Su Crucifissu Mannu (Sassari), n. 1	1	Bregma	C	Scraping and incision	Rhomboid depression of 7 x 2.5 cm obtained with scraping and followed by survival of the patient; central rounded perforation of 2.6 x 2.3 cm probably opened and widened through incision	Two different moments		
22	Su Crucifissu Mannu (Sassari), n. 13	2	Temporo-parietal; parieto-occipital	L, L	Scraping and sawing	1) Circular depression on the left temporo-parietal region of 5.4 x 5.5 cm and degrading in a heart-shaped central hole of 4.2 x 2.9 cm 2) a quadrangular depression in the left parieto-occipital region of 4.8 x 4.2 cm with a central ellipsoidal hole of 4 x 3.3 cm	Contemporary	-	
23	Taulera-Alghero (Sassari)	2	Fronto-parietal; parieto-occipital	R, L	Scraping and incision	1) Irregular ellipsoid-shaped depression on the right fronto-parietal region measuring 7 x 4.5 cm with a central triangular hole with diameters of 2.9 and 2.6 cm, 2) lanceolate orifice on the left lambdoid suture of 3 x 1.5 cm	Two different moments	-	
24	Perdalba-Sardara (Cagliari)	1	Parietal	L	Scraping	1) Small perforation of 0.8 x 0.3 cm 2) small perforation of 0.4 x 0.2 cm both surrounded by a scraped area	-	-	
25	Nuraxi Figus-	4	Frontal,	L, R	Drilling and	1) Lesion A on the right frontal bone,	Two different	-	

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49

	Gonnesa (Cagliari)		Parietal, occipital		scraping	2-3) lesion B and C on the left parietal bone 4) lesion D on the right occipital bone. Trepanations A, B and D are rounded crater-like lesions of 2.1 cm in diameter with a central hole of 0.8 cm, all performed by the drilling technique; lesion C is a quadrangular area of 4 x 4 cm with central rounded perforation of 2 cm in diameter performed with scraping followed by incision, in order to widen the orifice	moments	
26	Seulo (Cagliari)	3	Frontal, parietal	L	Scraping	1-3) depressed areas with a central hole (1.4 x 7, 1 x 0.85, 2.3 x 2 cm respectively)	Two different moments	-
27	Sisaia-Dorgali (Nuoro)	1	Parietal	R	Sawing	Irregular ellipsoidal lesion of 1.8 x 1.5 cm	-	P
28	Paradiso di Laorca (Lecco)	1	Frontal	R	Scraping	Depressed area of elliptic shape measuring 4.3 x 3 cm, with a central hole of 3.4 x 2.1 cm	-	-
29	Castenaso (Bologna)	1	Occipital	L	Drilling	Circular perforation of 3.5 x 3.7 cm	-	-
30	Vulci (Viterbo)	1	Parietal	R	Scraping	Elliptic depression measuring 2.3 x 2.1 cm, with a central hole of 1 x 0.8 cm	-	-
31	Monterozzi (Tarquinia)	1	Parietal	R	Drilling and sawing	Esagonal lesion of 2.7 x 2.3 probably obtained by practising six little rounded perforations that were then linked through incision ("boring-and-cutting" technique)	-	-
32	Imera (Palermo)	1	Frontal	R	Drilling	Circular perforation with a diameter of 1.3 cm	-	-
33	Imera (Palermo)	1	Parietal	L	Drilling	Perfectly circular hole of 0.9 cm in diameter with regular external border decreasing toward the inner table, with a drop-shaped gap	-	-
34	Pontecagnano (Salerno), PC 990	1	Parieto-occipital	R	Sawing	Quadrangular lesion of 4.8 x 4.8 cm	-	P
35	Pontecagnano	2	Frontal	L	Drilling	1) Depressed circular area of 3.5 cm in diameter with a central hole of 1	Contemporary	-

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49

	(Salerno), PC 4043					cm in diameter 2) a smaller circular lesion of 1.5 cm in diameter		
36	Poggiardo (Lecce)	1	Frontal	R	Scraping	Ovoid depression of 3.7 x 2.3 cm with a central perforation in the form of a lunar crescent; the remaining portion is occupied by a new bone formation	-	-
37	Contrada Santo Stefano, Gravina (Bari)	1	Parietal	L	Sawing	Irregularly ellipsoidal hole of 1.8 x 1.5 cm	-	-
38	Cassino	1	Parietal	R	Sawing	Oblong lesion of 2.8 x 5.3 cm	-	-
39	Alba Fucens (L'Aquila)	1	Occipital	R	Scraping	3 cm-diameter depressed area surrounds a central irregularly rounded 1.8 cm-diameter hole	-	-
40	Fidene (Roma)	1	Frontal	R	Sawing	Large opening of 5.4 x 4.8 cm	-	-
41	Rome (Villa Settibagni)	1	Parietal	L	Drilling	Regular perforation	-	-
42	Alberona (Foggia)	1	Parietal	L	Sawing	Quadrilateral lesion of 2.9 x 3.1 cm	-	-
43	Canosa (Puglia)	1	Parietal	R	Drilling	Regular margins and perpendicular walls, measuring 1.3 x 1.1 cm	-	-
44	Ticineto (Alessandria)	2	Parietals	L, R	Scraping and sawing	1) Lesion A is a lanceolate depression of 3 x 2 cm on the left parietal 2) lesion B is an ellipsoid hole on the right parietal obtained probably through incision1) irregular triangular hole of 1 x0.9 cm both obtained combining scraping with incision to widen the orifice	Two different moments	-
45	Cremona	1	Frontal	C	Scraping	Ovoid depressed area of 1.5 x 0.8 cm with an oblong perforation of 0.6 x 0.4 cm	-	-
46	Segesta (Trapani)	1	Occipital	L	Scraping and	Trepanation was obtained through scraping and the perforation was then	-	-

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49

					sawing	enlarged by incision		
47	Monte D'Argento (Latina), n. 11B	1	Occipital	L	Drilling	Small perforation of 0.45 cm in diameter	-	-
48	Monte D'Argento (Latina), n. 24	1	Parietal	L	Scraping	Eight-shaped orifice, which seems to have been produced by two contiguous holes of 3 x 2 cm	-	-
49	Sabbioneta (Vespasiano Gonzaga)	1	Parietal	R	Scraping	Lozenge-shaped depression of 7.5 x 5.5 cm with central trapezoid perforation measuring 2.5 x 1.4 cm	-	-
50	Osoppo (Udine)	1	Frontal	C	Scraping	Elliptic orifice of 3.6 x 2.9 cm	-	-
51	Otranto (Lecce)	16	Parietals, frontal	L, R, C	Drilling	Different size and depth, ranging from 0.5 to 3 cm in diameter: 8 are incomplete perforations of regular hemispheric shape, while 8 holes are complete perforations involving the bone in all its thickness, and producing a rounded conical shape hole with rounded walls	Contemporary	-
52	Populonia (Livorno)	1	Parietal	L	Scraping and sawing	Pentagonoid trepanation measuring 4.9 x 2.3 cm, obtained through scraping but there are also traces indicating the use of incision	-	-
53	Borgo Cerreto (Perugia)	1	Fronto-parietal	L	Drilling and scraping	Circular hole of 3.1 x 3 cm, with margins smoothed with a file	-	-
54	Comiso (Ragusa)	1	Parieto-temporal	L	Sawing and caustication	Depressed area of 6.8 x 4.9 cm with a central irregularly quadrangular-shaped perforation measuring 4.9 x 4.25 cm obtained through incision perfected in the inferior portion with caustication	-	-

Table 2. Summary of the cases of trepanation from Italy

Legend: L = left; R = right; C = central; P = present

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49

For Peer Review

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60



Figure 1 Map of Italy with the archaeological sites cited in the text

80x100mm (300 x 300 DPI)

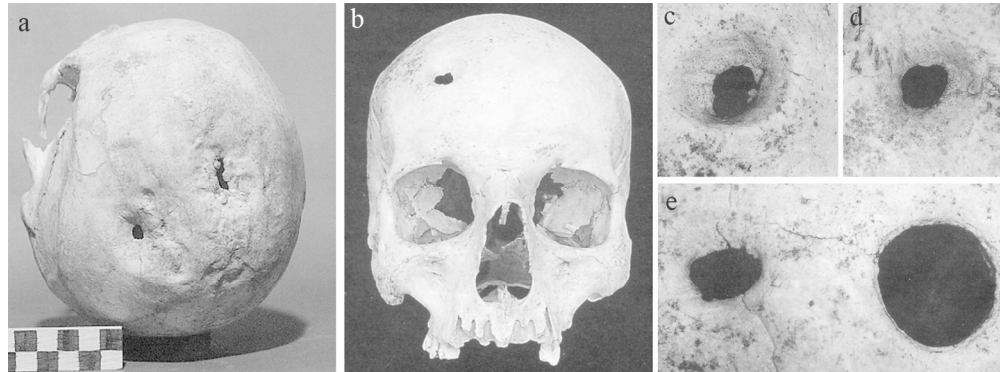


Figure 2 Trepanation from Catignano (Neolithic period, old adult female), showing two contemporary holes (a); trepanation in the skull of Nuraxi Figus-Gonnesa (Bronze Age, middle-aged adult male) (b), with 4 lesions obtained in at least two different interventions (c-e)

152x56mm (300 x 300 DPI)

Peer Review

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

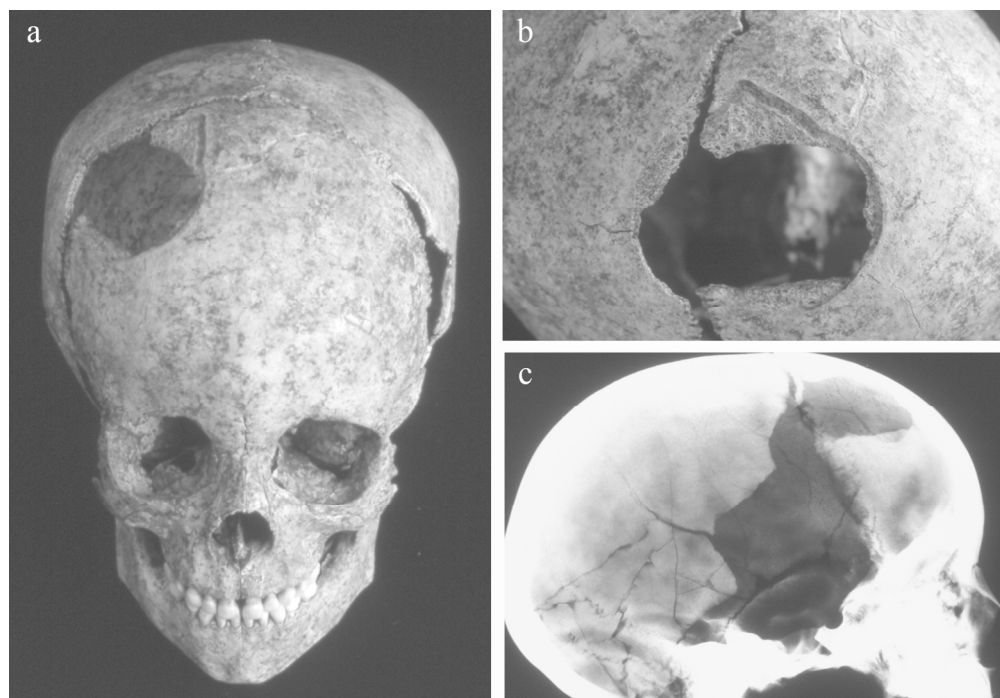


Figure 3 Trepanation from Fidene (2nd century AD) practised on a child of 5-6 years of age (a); detail of the lesion (b) and radiological examination showing evidences of hydrocephalus (c)

Review

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

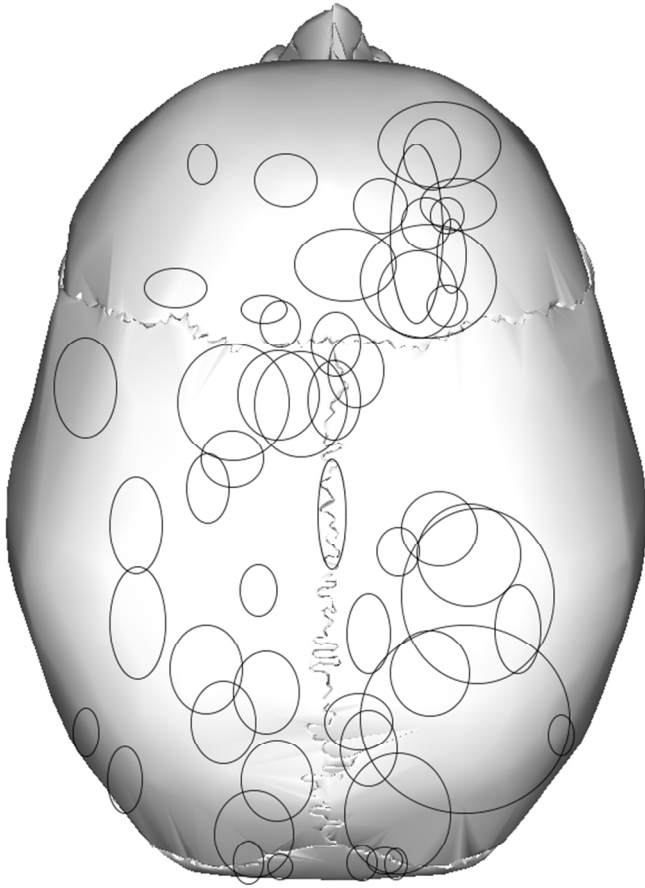


Figure 4 The approximate location of all lesions found on 53 skulls; the lesions on the skull from Otranto have not been represented

317x317mm (72 x 72 DPI)

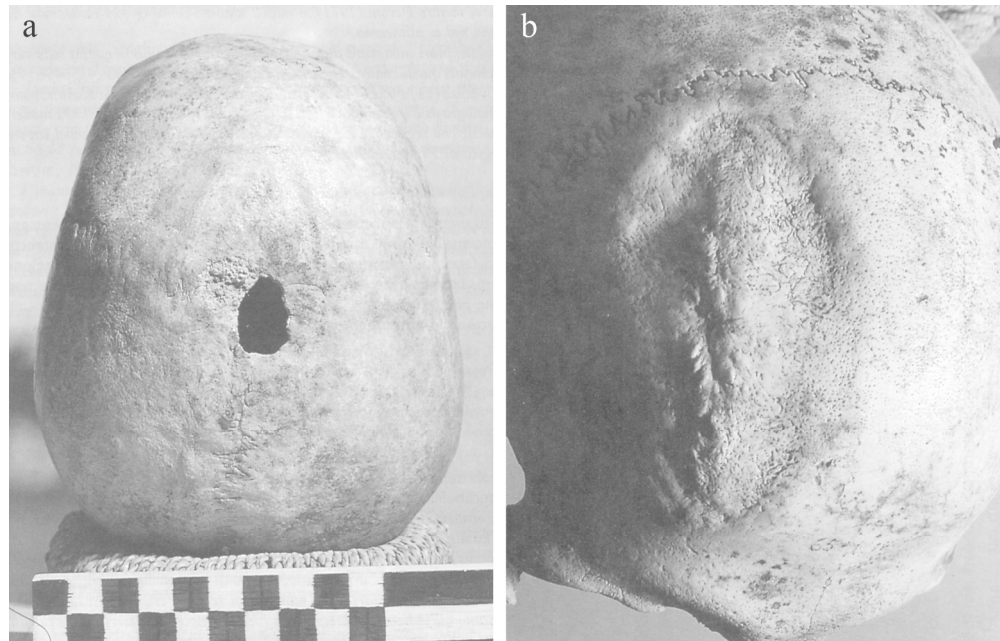


Figure 5 Trepanation from Scoglietto 6492 (Early Bronze Age, adult male) with an ellipsoidal depression and a central hole obtained through scraping (a); trepanation from Scoglietto 6511 (Early Bronze Age, 25-20 year-old-male) obtained by the technique of incision, which produced a lanceolate depression with no perforation, owing to the complete reparation of the orifice (b)

205x130mm (300 x 300 DPI)

Review

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

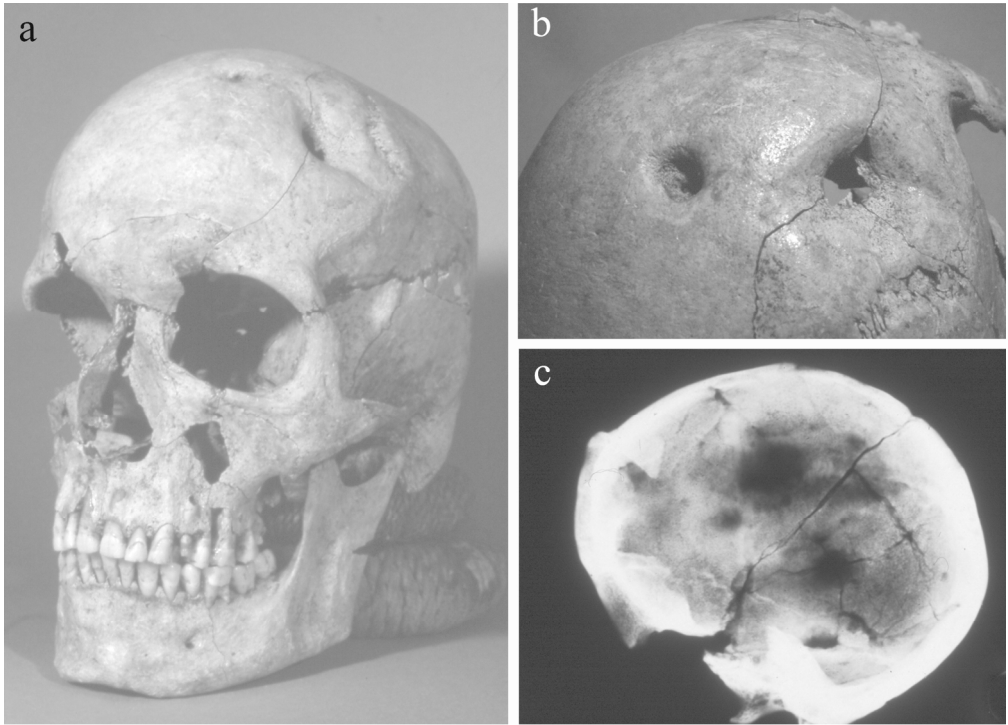


Figure 6 Trepanation from Pontecagnano 4043 (4th century BC, adult male) (a) with two contemporary trepanations obtained by drilling (b) and radiological examination (c)

Review

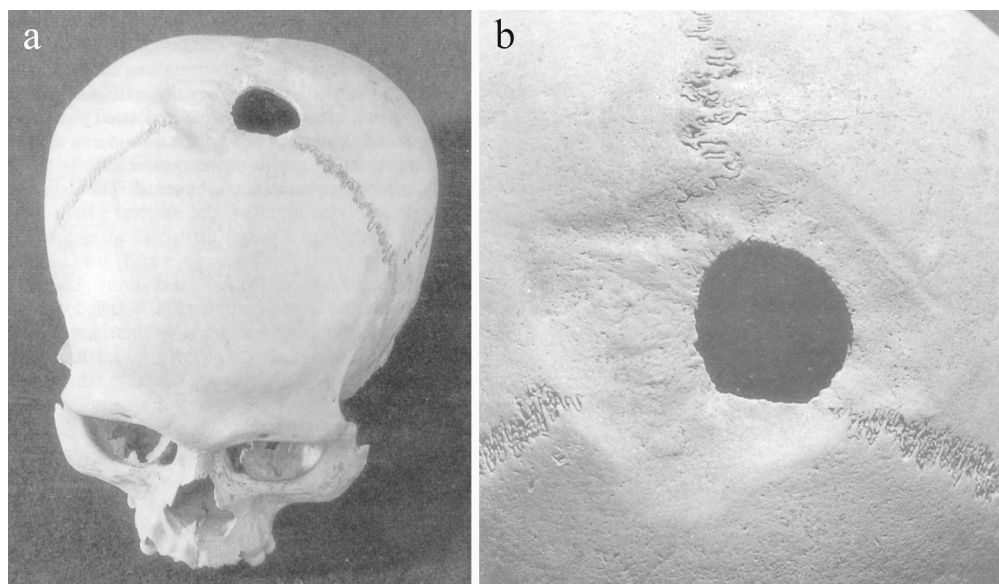


Figure 7 Trepanation from Su Crucifissu Mannu 1 (Early Bronze Age, 20-30 year-old-male) (a), showing a rhomboid depression obtained through scraping and a central rounded perforation probably opened and widened through incision (b)

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

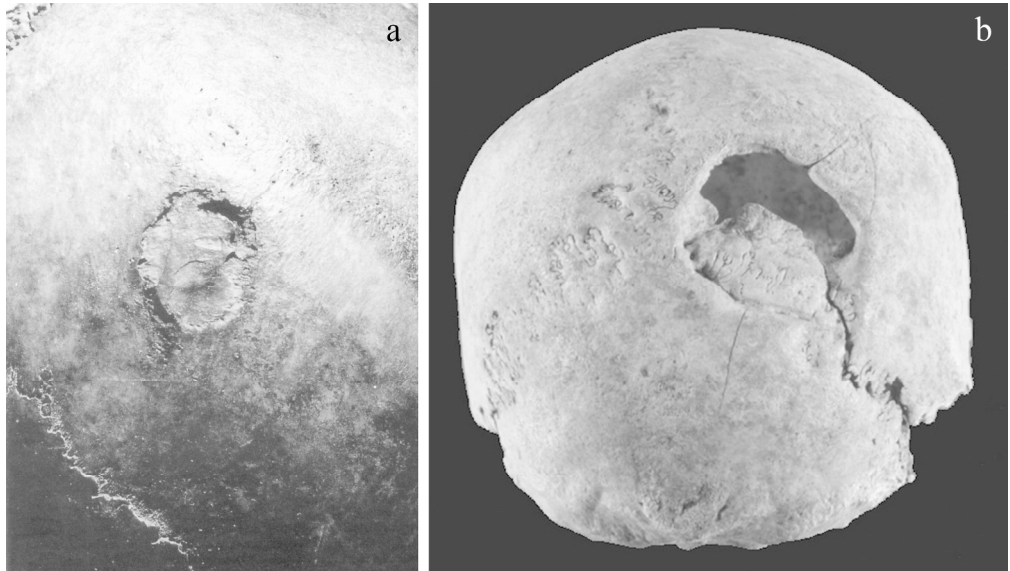


Figure 8 Trepanation from Sisaia Dorgali (Bronze Age, adult female) with the bone disc replaced in the trepanation hole, followed by resorption of the fragment (a); trepanation from Pontecagnano 990 (5-4th centuries BC, 40-45 year-old-male) with implantation of one half of the bone disc (b)

265x150mm (300 x 300 DPI)

Review

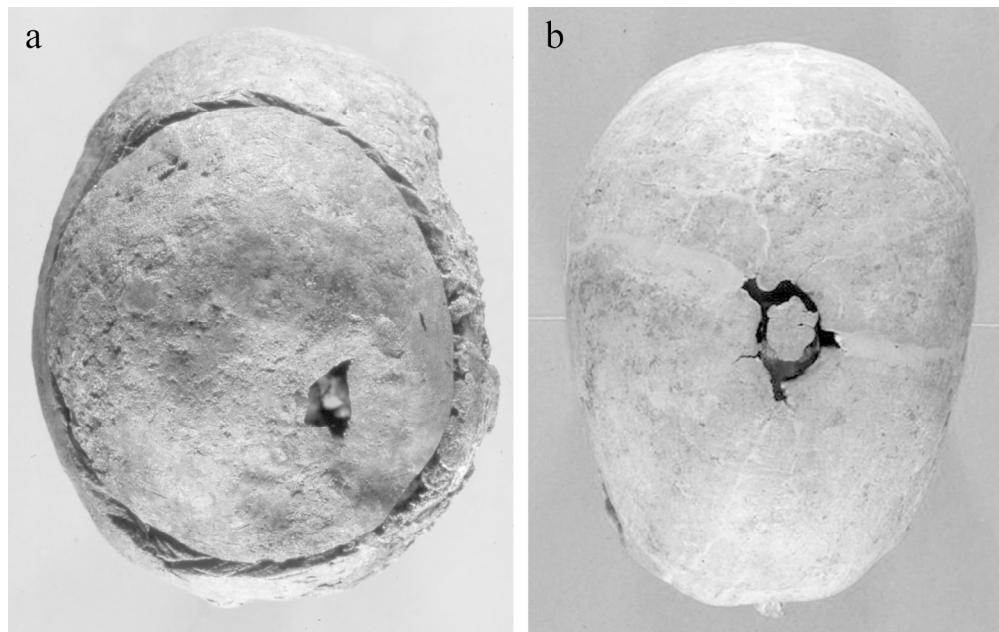


Figure 9 Trepanation of Vespasiano Gonzaga (1531-1591), performed to treat venereal syphilis, as attested by historical sources and by the luetic lesions visible on the skull surface (a); trepanation from Trasano (Neolithic) with the bone disc in situ, leading to suppose a ritual purpose for the surgical intervention (b)

200x126mm (300 x 300 DPI)

Review