One Big Family?
A Quantitative Look at Recurring Names on Judahite Private Jar-handle Impressions

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Abstract

This paper examines the phenomenon of recurring names on Judahite private jar-handle impressions. The large number of recurring names in this corpus has been noted as early as 1941 by David Diringer, who proposed that many stamp-bearers belonged to the same family. This phenomenon has rarely been discussed in subsequent literature, however. I offer a new statistical analysis, showing that the high recurrence of names among the private stamps cannot be due to mere chance and should rather be explained in terms of genealogical relations. These relations span at least two generations and involve between 30% and 60% of the stamp bearers. These results have two main implications. First, they vindicate Diringer's intuitions about the importance and genealogical nature of recurring names among the jar-handle impressions. Second, they suggest that the private jar-handles phenomenon probably had a longer time span than often assumed, lasting several decades rather than a handful of years before the Assyrian invasion of 701 BCE.

Keywords: Hebrew seals; stamped handles; Hebrew epigraphy; ancient Judah; southern Levant; quantitative methods

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1. Introduction

The phenomenon of so-called Judahite "private" (aka "official") jar-handle impressions stamped on *lmlk*-type jars has intrigued researchers for decades due to their wide distribution and ubiquity in late Iron Age Judahite sites (Vaughn 1999: 81–167, 198–218; Fox 2000: 225–235; Barkay and Vaughn 2004; Ussishkin 2004; Lipschits, Sergi, and Koch 2010: 22–27; Lipschits 2021: 49–55, 105–106, 127–128, 186–187, 192). While early authors often assumed these stamps to be potters' marks (Bliss and Macalister 1902: 118–119; Diringer 1941: 46, 49–50, 55, 89; Tufnell 1953: 341), recent research considers them as stamps of state officials involved in the (still mysterious) administrative process embodied by the *lmlk* jars (Vaughn 1999: 110–135; Lipschits 2021: 127–128).

This paper deals with an observation made by Diringer over 80 years ago, namely that the corpus of Judahite private stamped handles contains a large number of recurring names. In his own words, "I consider it useful to note a very interesting problem which occurred to me during my researches on private stamps. Some names and patronymics recur with a certain frequency, for which it would be difficult to exclude a connection" (Diringer 1941: 89).

Note that Diringer was not talking about individuals owning several seals—a well-attested phenomenon among the stamped handles—but rather about the recurrence of names (used as first names or patronyms) among *different* stamp bearers. He concluded that "It is quite possible, if not very probable, that the same family is concerned," a family he interpreted as "a species of 'dynasty' of potters" (Diringer 1941: 89). He also reconstructed a possible genealogical tree of this family,[1] spanning several generations, but also cautiously noted that some of the relations in the tree are uncertain (Diringer 1941: 90; Fig. 1).[2]

To the best of my knowledge, no work on the subject appeared ever since, except for several criticisms of Diringer's conclusions. Moscati criticized Diringer's genealogical tree on three grounds: (1) the material was too scarce to ensure genealogical relations (many of Diringer's relations were indeed backed by only one stamp), (2) many of Diringer's readings were uncertain, and (3) identical names do not necessarily imply identical persons (Moscati 1951: 73). Almost five decades later, Vaughn reached similar conclusions: "His [Diringer's] genealogical tree is built on many false readings [… which] were corrected in

1 Except for the first generation, which builds on a seal (*WSS* 150), Diringer's genealogical tree exclusively builds on private stamped handles.

2 Note that in a Hebrew paper published the same year, Yeivin proposed reconstructed genealogical trees of Judahite officials, based on a combination of names occurring in the Bible, on seals, seal impressions, and ostraca (Yeivin 1941). This work seems to have been completed independently of Diringer's, as they do not cite each other. Furthermore, Yeivin's work only makes marginal use of stamped handles. I am indebted to Prof. Yosef Garfinkel for this reference.

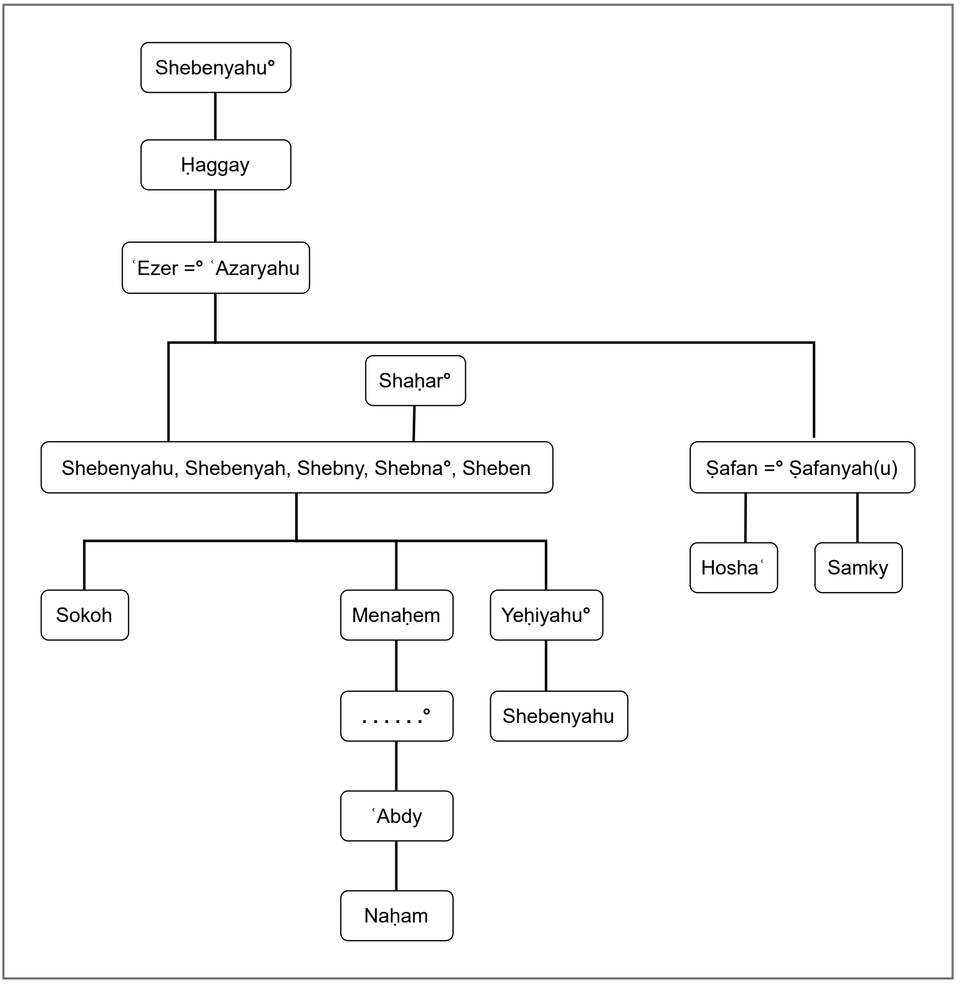

Fig.1. Diringer's reconstructed genealogical tree of the private jar stamp-bearers; the symbol ° marks uncertain relations (after Diringer 1941: 90).

subsequent publications.... When all of these new readings are taken into account, the genealogical tree presented by Diringer is impossible to construct. There are too many cases in which there are two or three patronyms for one PN. *It remains intriguing that so many PNN reoccur on these impressions,* but for the present, it is simply too speculative (if not impossible) to explain their frequency through a genealogical tree." (Vaughn 1999: 112, my emphasis). More recently, Lipschits reached the same conclusions, noting that "This [Diringer's] view did not gain widespread scholarly support and is no longer valid" (Lipschits 2021: 127), and "Most of these names have since been found to be of different patronyms than those assigned by Diringer" (ibid., 127, fn. 9).

Vaughn and Lipschits's comments on Diringer's work are unduly harsh, however. A close inspection of Diringer's tree shows that it is far from being built on "many false readings." In fact, only two readings used in the genealogical tree did not stand the test of time: Diringer's *šbnyhw yḥyhw* (Diringer 1941: 49–50, no. 12), which is now read as *šbnyh 'zryh* (*WSS* 702),[3] and Diringer's *mnḥm šbny* (Diringer 1934: 123–124, no. 6), which is now read as *mnḥm ybnh* (*WSS* 676). The other readings in the tree have not been challenged and match those found in standard references such as *WSS*. Furthermore, these two errors do not fundamentally alter the shape of Diringer's genealogical tree, as they only concern two low-hanging branches.

But the important point here, rather than the tree's shape, is Diringer's claim that many names on the private handle impressions recur. Indeed, although he criticized Diringer's genealogical tree, Vaughn conceded that the high number of recurring names is "intriguing." I am unaware of other publications that have tackled this "intriguing" question ever since and have, therefore, decided to take a fresh look at Diringer's hypothesis. In this paper, I address this question using a statistical approach. By comparing the patterns of recurring names on private jar handles and on provenanced Iron Age Hebrew seals and bullae, I show that the recurrence of names on the stamped handles is statistically highly significant and that it most probably hints at genealogical relations among the stamp bearers. These quantitative conclusions vindicate Diringer's qualitative intuitions from over eighty years ago.

2. Methods

Our method consists in comparing the pattern of recurring names on the private stamped handles and on Judahite Iron Age IIB–C seals and bullae in order to check if the former significantly deviates from the latter. Let us first define these two corpora.

2.1. Corpus of stamped handles

Our analysis is based on all provenanced Judahite "private" jar-handle impressions satisfying the following criteria:

1. The stamp bears a name and a patronym;[4]

3 Note, however, that Diringer did mention as *šbnyh*[*w*] *'zryhw* an alternative reading for this stamp (Diringer 1941: 49–50, no. 12).

4 This excludes several handles with no patronym (*WSS* 663: *l'lyqm n'r ywkn*; *WSS* 685: *lnr'* [uncertain reading]; *WSS* 690: *l'bdy*). Note, however, that both *WSS* 685 (provided its reading is correct) and *WSS* 690 feature repeated names (cf. *WSS* 684: *nḥm 'bdy*; *WSS* 686: *nr' šbn'*).

2. The reading of the inscription is clear with no major disagreements among scholars;[5] and
3. No data indicates that the stamp does not belong to the corpus of private jar handles related to *lmlk* jars.[6]

Among these stamps, the number of stamp bearers is decided based on the following criteria:

4. A hypocoristic and the corresponding full theophoric name (e.g., *ʿzr* and *ʿzryhw*) are considered equivalent;[7]
5. Names differing only by *matres lectionis* are considered equivalent (e.g., *yhwḥl* and *yhwḥyl*); and
6. Stamp bearers sharing identical or equivalent name and patronym are assumed to be the same person.

Note that all these criteria conform to standard practice in stamped-handle research (*WSS*: 242–263; Vaughn 1999: 198–218). Their application resulted in 27 stamp bearers listed in Table 1, which updates the data available to Diringer in 1941 in the following ways:

1. It adds seven stamp bearers who were unknown in 1941 and whose stamps were first published in 1947 (no. 1), 1959 (no. 11), 1962 (nos. 7, 14), 2000 (no. 6), 2009 (no. 2), and 2010 (no. 18).
2. It corrects some of the readings that were available in 1941:

   a. No. 3 is now read as *bky šlm* (*WSS* 666) instead of *bky šlmh* (Diringer 1934: 341–342, no. 10a).
   b. No. 8 is now read as *ksl' zk'* (*WSS* 674) instead of *ks' zk'* (Grant and Wright 1939: 84, no. 10a).
   c. No. 9 is now read as *mnḥm ybnh* (*WSS* 676) instead of *mnḥm šbny* (Diringer 1934: 123–124, no. 6).
   d. No. 9 is now read as *mnḥm ywbnh* (*WSS* 678) instead of *lpn bn yḥny* (Diringer 1941: no. 14).

5 This excludes *WSS* 668 (unclear first name: *hwšʿ* or *hwšʿm*) and *WSS* 675 (unclear patronym: *ypy*[…] or *rpy*[…]).

6 The main criterion in the literature for excluding a stamped handle from the private jar-handles corpus is a dating of the jar to the Iron Age IIC rather than the Iron Age IIB. This criterion excludes WSS 664 (*lḥnh bt ʿzryh*), often dated to the Iron Age IIC (though see the remarks in *WSS* 644 for an alternative view) and a recently published stamped handle from Lachish Level II (*lyrmyhw bn ṣpnyhw*; Garfinkel et al. 2021: 450–451, Fig. 28), also dated to the Iron Age IIC.

7 An additional, non-theophoric, case of names considered equivalent here is *'ḥ'* for *'ḥ'mr* (WSS 705–706).

e. No. 12 is now read as *nḥm hṣlyhw* (*WSS* 682) instead of *nḥmh ṣlyhw* (Diringer 1941: no. 10). Note that the difference only concerns the parsing of the string, not the identification of the letters.

f. No. 19 is now read as *ṣpn ʾbmʿṣ* (*WSS* 695), whereas the sole item known to Diringer had a small lacuna resulting in the (otherwise correct) reading *ṣpn ʾ*[.]*mʿṣ*.

g. No. 21 is now read as *rpʾy yhwkl* (*WSS* 700) rather than *rpty yhwkl* (Diringer 1934: 119–120, no. 1).

h. No. 23 is now read as *bnyh ʿzryh* (*WSS* 702; Barkay and Vaughn 1996: 71, n. 20), whereas Diringer hesitated between *šbnyh ʿzryhw* and *šbnyh yḥyhw* (Diringer 1941: no. 12) and favored the latter.

i. No. 25 is now read as *šlm ʾḥʾmr* (*WSS* 706) rather than *šlm ʾḥsmk* (Diringer 1941: no. 5).

j. No. 27 is now read as *tnḥm ngb* (*WSS* 708), whereas Immanuel Ben-Dor hesitated between *tnḥm ngb* and *tnḥ mngb* (in Grant and Wright 1939: 84, no. 9). As in no. 12, above, the difference concerns the parsing of the string, not the identification of the letters.

Table 1. Corpus of jar stamp bearers considered in this paper; recurring names are marked in bold. Note that the preposition *l* ("belonging to") appearing on many stamps and the filiation mark *bn* ("son of") appearing on *WSS* 688 have been omitted for the sake of clarity.

Person	References
ʾḥzyhw ***tnḥm***	*WSS* 665
ʾḥmlk *ʿmdyhw*	Seligman 2009
bky ***šlm***	*WSS* 666
hwšʿ ***ṣpn***	*WSS* 667
ḥsdʾ yrmyhw	*WSS* 670
ḥšy ***ʾlšm*[ʿ]**	Shoham 2000: No. P2
yhwḥl/yhwḥyl ***šḥr***	*WSS* 672/673
kslʾ zkʾ	*WSS* 674
mnḥm ybnh/yhwbnh/ywbnh	*WSS* 676/677/678
mšlm ʾḥmlk	*WSS* 679
mšlm *ʾlntn*	*WSS* 680
nḥm *hṣlyhw*	*WSS* 681/682
nḥm *ʿbdy*	*WSS* 684
nrʾ/nry ***šbnʾ/šbnyh/šbnyw***	*WSS* 686/687/688
sm*[*k*]*/sm*[*ky*] *ṣpnyhw	*WSS* 689

Person	References
‘zr *ḥgy*	*WSS* 691
ṣdq ***smk***	*WSS* 694
ṣmḥ ***’lšm‘***	Lipschits 2010
ṣpn *’bm‘ṣ*	*WSS* 695
ṣpn ‘zr/‘zryhw	*WSS* 696/697/698
rp’y yhwkl	*WSS* 700
šbn’ šḥr	*WSS* 701
šbnyhw/šbnyh ‘zryhw/‘zryh	*WSS* 702/703
šwkh ***šbn’***	*WSS* 704
šlm *’ḥ’/’ḥ’mr*	*WSS* 705/706
tnḥm *mgn*	*WSS* 707
tnḥm *ngb*	*WSS* 708

Note that half of the abovementioned corrections are minor, dealing with a single letter (Nos. 3, 8, 19, 21) or parsing issues (Nos. 12, 27). Errors in such early readings were often due to many handles’ poor preservation; these errors were corrected thanks to the later discovery of better-preserved parallel items. Also, as noted above, only two of these erroneous readings (Nos. 9, 23) were included in Diringer’s 1941 genealogical tree, but they did not significantly impact its shape, as they only concerned two low-hanging branches.

2.2. Corpus of seals and bullae

Our corpus of seals and bullae consists of all the provenanced Iron Age IIB–C inscribed Judahite seals and bullae bearing a clear first name and patronym.[8] Other criteria for selection in this corpus are identical to those used above for stamped handles except Criterion 3, which only applies to handles. The application of these criteria resulted in 80 seal bearers listed in Table 2.

The rationale for using seals and bullae as a comparative corpus lies in the fact that they constitute the closest possible corpus to the stamped handles. Both corpora lie within the realm of sigillography, date from the Iron Age II, are written in Hebrew, originate in Judah, and are commonly assumed to comprise names of notables and state officials. I am aware of one potential limitation of this approach: Much of the corpus of Judahite seals and bullae

8 For an up-to-date list of provenanced Iron Age Hebrew seals and seal impressions, see Levy (2023) and the database *Hebrew Stamp Seals (HSS,* www.hebrewseals.com).

Table 2. Eighty seal bearers attested on seals and bullae featuring a name and a patronym. Items bearing no patronym or having uncertain readings were excluded; items bearing a papponym (grandfather's name) were kept, but only the first name and patronym were considered in the study. Note that papponyms, as well as the preposition *l* ("belonging to") appearing on many seals, have been omitted for the sake of conciseness.

	Seal bearer		Seal bearer
1.	*'ḥ'b b'd'l* (*WSS* 52)	41.	*yhwkl bn 'ḥmlk* (Mazar and Livyatan Ben-Arie 2015: No. B8)
2.	*'ḥ'mh 'lyhw* (Mähner 1992)	42.	*yhwkl bn yhw*[*ḥ*]*y* (*WSS* 524)
3.	*'ḥy'b bn yhw'b* (*WSS* 427)	43.	*yhwkl bn šlmyhw* (Mazar and Livyatan Ben-Arie 2015: No. B9)
4.	*'ḥy'b bn mnḥm* (Mendel-Geberovich, Chalaf, and Uziel 2020: No. 9)	44.	*yqmyhw ḥlṣyhw* (Mazar and Livyatan Ben-Arie 2018: No. B10)
5.	*'ḥymh ḥnnyh* (*WSS* 429)	45.	*yrḥm*[']*l bn nḥm* (Mazar and Livyatan Ben-Arie 2018: No. B2)
6.	*'ḥmlk smk* (*WSS* 59)	46.	*yrmyhw bn ṣpnyhw* (*WSS* 530)
7.	*'kr bn mtnyhw* (Mendel-Geberovitch et al. 2019)	47.	*yšm''l nryhw* (*WSS* 210)
8.	*'lyhw 'l'r* (Sass 2008)	48.	*yš'yhw 'mryhw* (*WSS* 212)
9.	*'lyšb bn 'šyhw* (*WSS* 70–72)	49.	*knyhw bn hdyhw* (*WSS* 220)
10.	*'lyqm bn 'whl* (*WSS* 437)	50.	*m'syhw 'lyqm* (Mendel-Geberovich, Chalaf, and Uziel 2020: Fig. 5)
11.	*'lyqm yhwzrḥ* (Klingbeil et al. 2019: nos. A, B)	51.	*mk'ḥ 'myḥy* (Finkielsztejn and Gorzalczany 2010)
12.	*'lyqm mk'* (Shoham 2000: 81)	52.	*mky*[*hw*] *bn ḥṣy* (*WSS* 541)
13.	[']*lyš' y'wš* (Mazar and Livyatan Ben-Arie 2015: no. B3)	53.	*mšlm mqnyhw* (Vukosavović and Chalaf 2020: Fig. 4)
14.	*'lntn bn blgy* (*WSS* 440–441)	54.	*mtnyhw yšm''l* (*WSS* 568)
15.	*'lšm' bn smkyhw* (*WSS* 448)	55.	*mtnyhw 'zryhw* (*WSS* 261)
16.	*'prḥ 'ḥyhw* (*WSS* 450)	56.	*nḥm bn 'nnyhw* (*WSS* 571)
17.	*'ryhw 'zryhw* (*WSS* 94)	57.	*nḥm bn š'lh* (*WSS* 573)
18.	*blgy bn dlyh*[*w*] (*WSS* 458)	58.	*nryhw dmlyhw* (*WSS* 581)
19.	*bnyhw bn hwš'yhw* (*WSS* 459)	59.	*ntnyhw bn y'š* (Ornan et al. 2008: no. 1)
20.	*brkyhw bn mlky*/*mlkyhw* (*WSS* 463)	60.	*sl' bn 'lyrm*[*h*] (Mazar and Livyatan Ben-Arie 2015: No. B14)
21.	*gdyhw bn 'zr* (*WSS* 467)	61.	*s'ryhw bn šbnyhw* (Ben-Ami and Misgav 2016: Fig. 2)
22.	*gdlyhw bn pšḥwr* (Mazar and Livyatan Ben-Arie 2015: No. B4)	62.	*'dyhw 'ḥmlk* (*WSS* 293)
23.	*gmryhw bn mgn* (*WSS* 469)	63.	*'dyhw yš'yhw* (Mazar and Livyatan Ben-Arie 2018: No. B9)

	Seal bearer		**Seal bearer**
24.	*gmryhw [bn] špn* (*WSS* 470)	64.	*‘zryhw bn ḥlqyhw* (*WSS* 596)
25.	*dlyhw [b]n gdlyhw* (Mazar and Livyatan Ben-Arie 2015: No. B5)	65.	*‘zrqm mkyhw* (*WSS* 599)
26.	*dlyhw b[n] hwš‘yhw* (*WSS* 474)	66.	*‘lyhnh bt g’l* (Ben-Ami and Misgav 2016: Fig. 3)
27.	*ḥgy yš’l* (*WSS* 147)	67.	*rp’yhw bn ’prḥ* (*WSS* 626)
28.	*ḥgy bn šbnyhw* (*WSS* 150)	68.	*rp’yhw bn ṣpnyh* (Vukosavović and Chalaf 2020: Fig. 2)
29.	*ḥz[q]yhw ’[ḥ]z mlk yhd[h]* (Mazar 2015)	69.	*rp’yhw šlm* (Reich and Shukron 2009: 358–359)
30.	*ḥlqyhw bn m’s* (*WSS* 498)	70.	*š’lh bn mšlm* (Ben-Ami and Tchekhanovets 2010: 70–72)
31.	*ḥmy’hl bt mnḥm* (*WSS* 35)	71.	*šbnh ’ḥ’b* (*WSS* 350)
32.	*ḥnmlk yšm‘’l* (*WSS* 500)	72.	*šbnyhw smk* (Faust 2011)
33.	*ḥnnyhw bn ’ḥ’* (*WSS* 503)	73.	*šlm klkl* (Lipschits 2011)
34.	*ḥnnyh[w] bn ṭbš* (Reich and Sass 2006: No. 1)	74.	*šm‘yhw bn y’zny* (*WSS* 636)
35.	*ṭbšlm yhwkl* (Reich and Sass 2006: No. 2)	75.	*šm‘yhw [b]?[n]? mḥsyhw* (*WSS* 637)
36.	*y’znyhw bn m‘šyhw* (*WSS* 511)	76.	*šm‘yhw [b]n plṭyhw* (*WSS* 638)
37.	*yd‘yhw ’wš’* (Ornan et al. 2008: No. 3)	77.	*špṭyhw bn dmly[hw]* (*WSS* 643)
38.	*yd‘yhw bn mšlm* (*WSS* 515)	78.	*špṭyhw smk* (Vainstub and Ben-Shlomo 2016)
39.	*yhw’l my’mn* (*WSS* 523)	79.	*špṭyhw ‘šyhw* (*WSS* 385)
40.	*yhwḥn bt pq‘t* (Reich and Sass 2006: No. 3)	80.	*špṭyhw bn ṣpn* (*WSS* 644)

dates to the Iron Age IIC and is, therefore, slightly later than the stamped handles (commonly dated to the late Iron Age IIB). Yet, no better epigraphic corpus of Hebrew names and patronyms can be used for this task. The only alternative would be to use names and patronyms occurring on Iron Age Hebrew ostraca. However, these ostraca suffer from exactly the same problem: The bulk of the corpus (Lachish and Arad ostraca) dates from the Iron Age IIC rather than the Iron Age IIB. Furthermore, most of these names seem related to the military realm and, thus, might reflect a different segment of society. These considerations strongly suggest that Iron Age IIB–C inscribed Judahite seals and bullae offer the closest available source of names and patronyms for comparison with the stamped handles.

2.3. Quantifying the recurrences

Having established our two corpora, the first step towards deciding whether private jar-handle impressions feature an unusual pattern of recurring names is to quantify these recurrences. We, therefore, need to establish quantitative criteria for describing the pattern of recurring names. I propose the following parameters:

1. **Number of recurring names.** This parameter consists of the number of names that appear more than once in a corpus. Of the 37 names in the corpus of stamped handles, 11 recur: *'ḥmlk*, *'lšm'*, *mšlm*, *nḥm*, *smk/smky*, *'zr/'zryh/'zryhw*, *ṣpn/ṣpnyhw*, *šbn'/šbnyh/šbnyhw*, *šḥr*, *šlm*, and *tnḥm*.
2. **Number of persons with recurring names**. This parameter consists of the number of persons bearing a recurring name (as first name or patronym). Of the 27 individuals in the corpus of handles, 23 are such persons, namely all the stamp-bearers in Table 1 except for Nos. 5, 8, 9, and 21.
3. **Number of name matches**. The term *name match* designates here any match between one person's first name or patronym and another person's first name or patronym. Our corpus of stamped handles has 25 name matches,[9] which can be of three types:

    a. **First name matches**. Two persons sharing the same first name (homonyms), e.g., *tnḥm mgn* and *tnḥm ngb*.
    b. **Patronym matches.** Two persons sharing the same patronym, e.g., *nr' šbn'* and *šwkh šbn'*. These are cases of potential siblings because if the first and second *šbn'* are the same person, then *nr'* and *šwkh* are siblings.
    c. **Cross-matches**. This is the case when one person's patronym matches another person's first name, e.g., *hwš' ṣpn* and *ṣpn 'zr*. These represent potential genealogical relations because if the first and second *ṣpn* are the same person, then *hwš' ṣpn* is the son of *ṣpn 'zr*.

Note that in the above definitions, equivalent names, in the sense of Criteria 4 and 5 (see Section 2.1), count for a single name.

9 The 25 name matches are: 1-26, 1-27, 2-10, 3-25, 4-15, 4-19, 4-20, 6-18, 7-22, 10-11, 12-13, 14-22, 14-23, 14-24, 15-17, 15-19, 15-20, 16-20, 16-23, 19-20, 20-23, 22-23, 22-24, 23-24, 26-27 (numbers refer to Table 1).

2.4. Comparison procedure

I propose a simple statistical experiment to compare the pattern of recurring names in the two corpora. The difficulty is that we are comparing a corpus of 27 persons (handles) with a corpus of 80 persons (seals and bullae). In order to obtain meaningful results, samples of equal size are preferred. Therefore, subsets of 27 persons are used, chosen out of the 80 persons attested on seals and bullae. Following standard statistical procedure, random subsets of 27 persons are selected from the 80 seal bearers and the value of the three parameters is computed for each subset.[10] This results in a distribution of values for each parameter, as the values vary from sample to sample. This distribution is then compared to the value of the parameters observed for the stamped handles (i.e., 11, 23, 25, as noted above). If the probability of attaining similar (or higher) parameter values for the seals and bullae is lower than 5% (a commonly used threshold in statistical hypothesis testing), then the stamped handles are considered to *significantly* deviate from the seals and bullae.[11] The experiment used one million random samples of 27 seal bearers generated by a computer program written by the author in the Python programming language. The complete Python code and data files are provided in the appendix and are also available online to ensure transparency and repeatability of the results.[12]

3. Results

3.1. Result 1: Statistical significance of the recurring names

The distributions of our three parameters for seals and bullae vs. private stamps are illustrated in Figures 2–4 and summarized in Table 3. They show that seals and bullae feature an average of approximately eight recurring names, 14 persons with recurring names, and 10 name matches. These numbers are all below the values observed for stamped handles, which are 11, 23, and 25, respectively. The difference is especially strong for the third parameter (name matches), where

10 Note that the number of possible subsets of 27 persons in a set of 80, the so-called mathematical binomial coefficient, noted , amounts to over 1.5×10^{21} (1.5 sextillions). This number is too high for an exhaustive enumeration of all subsets, even on a fast computer. Therefore, random sampling is used (following standard statistical practice) to approximate this distribution.

11 In statistical parlance, this quantity is referred to as the *p-value* of a statistical test. The hypothesis I seek to infirm, namely that of a similar distribution between stamped handles on one hand, and seals and bullae on the other hand, is referred to as the *null hypothesis*. The distribution of seals and bullae would then be referred to as the *null distribution*.

12 The data files and source code of the program can be found on the GitHub repository at https://github.com/Eythan31/Stamped-handles-repeated-names.

stamped handles feature over double the value observed for seals and bullae (25 and 10, respectively). Yet, we still need to determine the statistical relevance of the observed differences. We may achieve this by computing the probability that a random set of 27 seal bearers (taken among the seals and bullae) matches (or exceeds) the values observed for stamped handles. These values amount to 8.7%, 0.18%, and 0.01%, respectively (Table 3; see also the red vertical lines in Figs. 2–4). The observed probabilities for the number of persons with recurring names (0.18%) and name matches (0.01%) are significantly lower than the standard 5% statistical threshold.

These results establish beyond doubt that the pattern of recurring names on jar handles differs significantly from the one occurring on seals and bullae.[13] The remainder of the discussion will focus on name matches, as it is the parameter that most precisely characterizes the pattern of recurrences and is also the one for which stamped handles differ the most from seals and bullae.

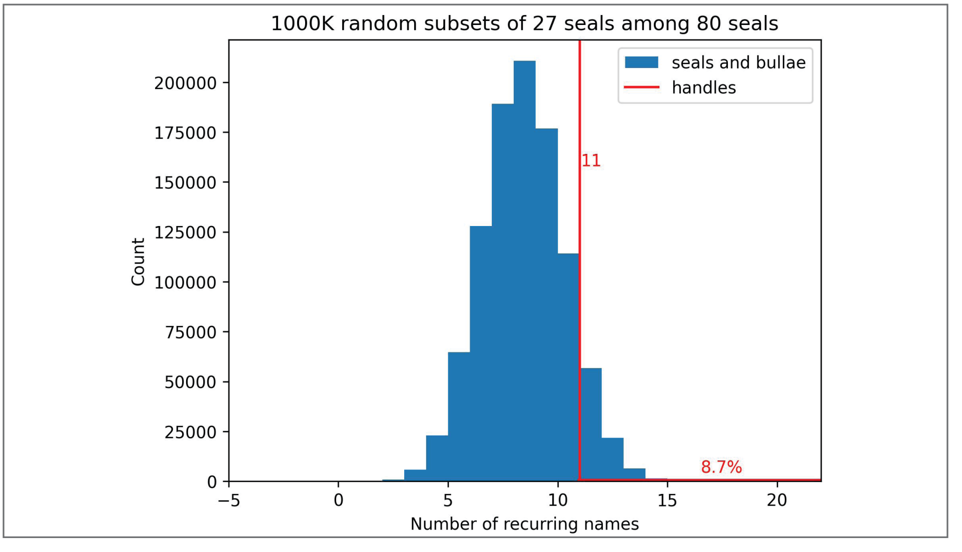

Fig. 2. Distribution of the number of recurring names for one million randomly chosen subsets of 27 seal bearers from a corpus of 80 seal bearers (on seals and bullae). The distribution has an average of 7.9, a mode (peak value) of 8, a median of 8, a standard deviation of 1.88, and a 95th percentile of 11. The corresponding value for stamped handles (11) is marked in red. The probability of attaining such a high (or higher) value among seals and bullae (8.7%) is indicated in the lower right corner.

13 In statistical parlance, we say that we *reject* the hypothesis of a similar pattern of recurrences between the two corpora (the so-called *null hypothesis*).

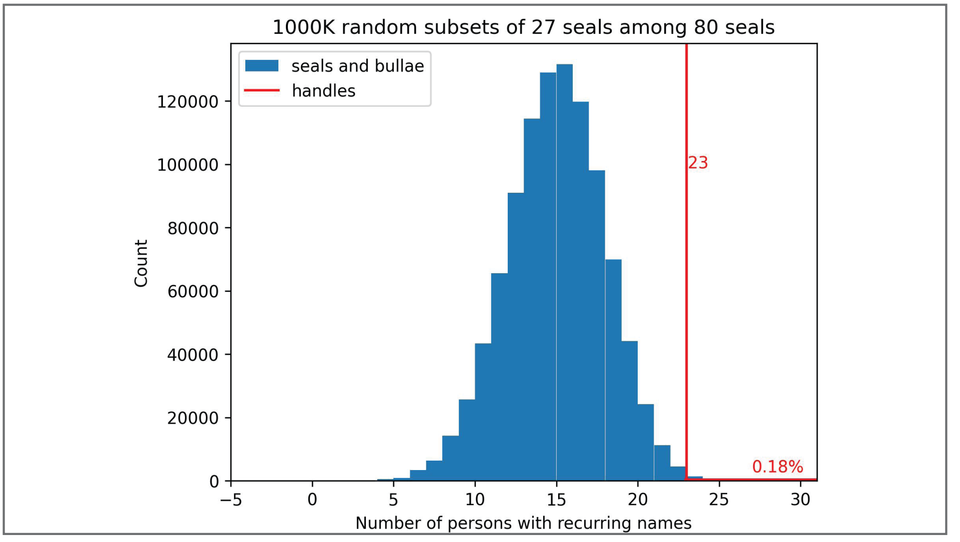

Fig. 3. Distribution of the number of persons with recurring names for one million randomly chosen subsets of 27 seal bearers from a corpus of 80 seal bearers (on seals and bullae). The distribution has an average of 14.4, a mode (peak value) of 15, a median of 15, a standard deviation of 2.99, and a 95th percentile of 19. The corresponding value for stamped handles (23) is marked in red. The probability of attaining such a high (or higher) value among seals and bullae (0.18%) is indicated in the lower right corner.

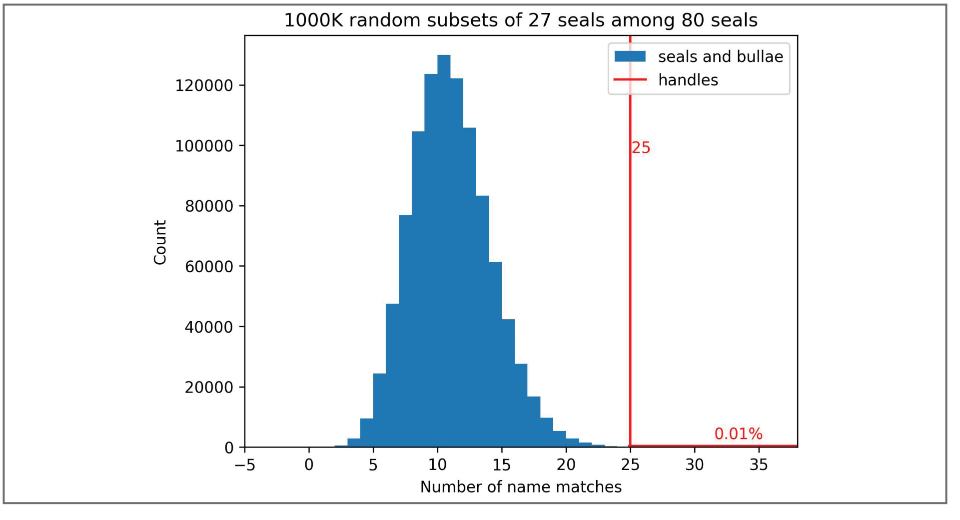

Fig. 4. Distribution of the number of name matches for one million randomly chosen subsets of 27 seal bearers from a corpus of 80 seal bearers (on seals and bullae). The distribution has an average of 10.5, a mode (peak value) of 10, a median of 10, a standard deviation of 3.12, and a 95th percentile of 16. The corresponding value for stamped handles (25) is shown in red. The probability of attaining such a high (or higher) value among seals and bullae (0.01%) is indicated in the lower right corner.

Table 3. Summary of the results of our statistical experiment comparing the number of recurring names, persons with recurring names, and name matches, among stamped handles, on the one hand, and seals and bullae, on the other hand. The last column refers to the probability that a randomly chosen set of 27 seal bearers (among seals and bullae) reaches a value as large (or larger) than the stamped handles. The results show high statistical significance of the number of persons with recurring names and the number of name matches.

	Handles	Seals and bullae (average)	Seals and bullae (probability of matching the handles)
Recurring names	11	7.9	8.7%
Persons with recurring names	23	14.4	0.18%
Name matches	25	10.5	0.01%

3.2. Result 2: Statistical significance of the cross-matches

Recall that name matches can be of three types: first-name matches (homonyms), patronym matches (potential siblings), and cross-matches (one person's patronym matching another person's first name, representing potential genealogical relations). Let us, therefore, perform the same experiment as above but for one type of name match at a time. The results are illustrated in Figures 5–7 and summarized in Table 4. They show that seals and bullae feature an average of 3.3 first-name matches, 2.4 patronym matches, and 4.7 cross-matches, values below those observed for stamped handles: 5, 5, and 15, respectively. The difference is especially striking for cross-matches, where stamped handles feature over three times the average number observed for seals and bullae (15 and 4.7, respectively). Here, too, we need to determine the statistical relevance of these observations. As before, we do so by computing the probability that a random set of 27 seal bearers (taken among the seals and bullae) will match (or exceed) the values observed for stamped handles. The resulting probabilities are 23.4% for first-name matches, 10.1% for patronym matches, and 0.002% for cross-matches (Table 4).

Thus, only cross-matches produced a probability lower than the standard 5% statistical threshold. This implies that the high statistical significance found above for the number of name matches (0.01%) is mainly due to cross-matches (0.002%) rather than first-name matches (23.4%) or patronym matches (10.1%). Furthermore, the associated probability (0.002%) is strikingly low, leaving no possible doubt as to the exceptional nature of the observed number of cross-matches among the handles.

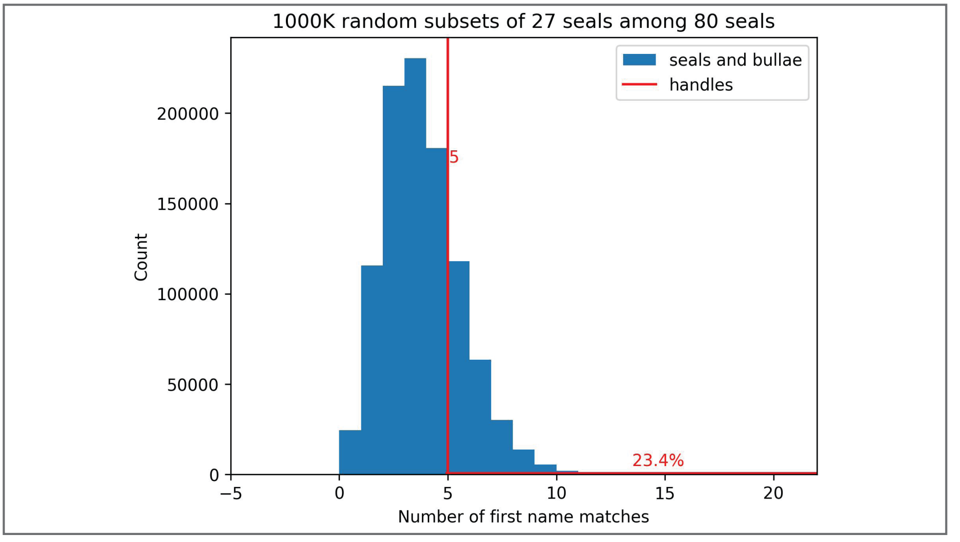

Fig. 5. Distribution of the number of first-name matches for one million randomly chosen subsets of 27 seal bearers from a corpus of 80 seal bearers (on seals and bullae). The distribution has an average of 3.3, a mode (peak value) of 3, a median of 3, a standard deviation of 1.79, and a 95th percentile of 7. The corresponding value for stamped handles (5) is marked in red. The probability of attaining such a high (or higher) value among seals and bullae (23.4%) is indicated in the lower right corner.

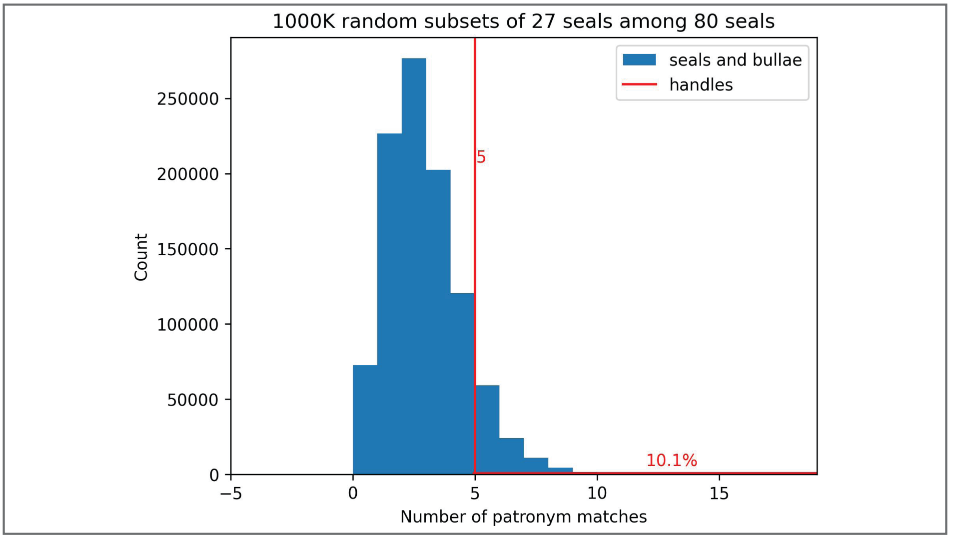

Fig. 6. Distribution of the number of patronym matches for one million randomly chosen subsets of 27 seal bearers from a corpus of 80 seal bearers (on seals and bullae). The distribution has an average of 2.4, a mode (peak value) of 2, a median of 2, a standard deviation of 1.58, and a 95th percentile of 5. The corresponding value for stamped handles (5) is shown in red. The probability of attaining such a high (or higher) value among seals and bullae (10.1%) is indicated in the lower right corner.

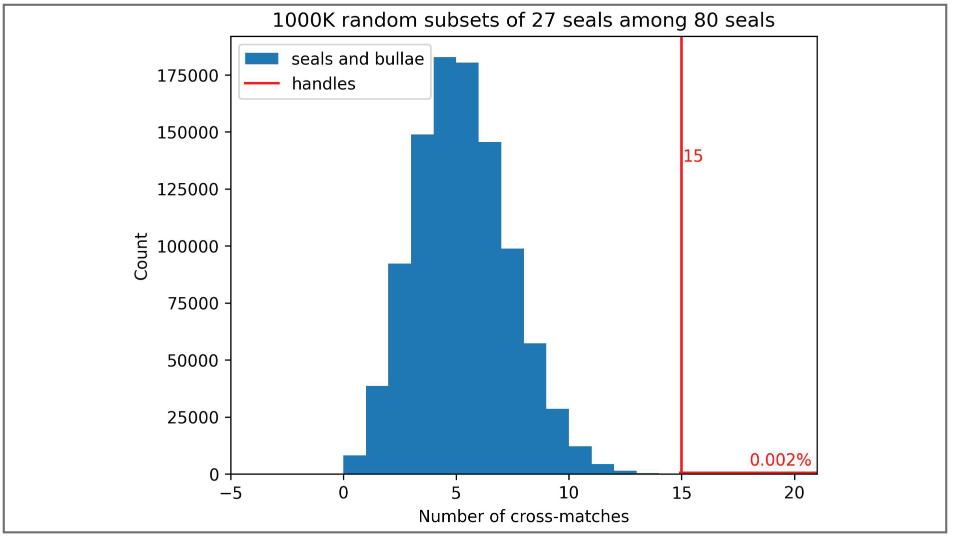

Fig. 7. Distribution of the number of cross-matches for one million randomly chosen subsets of 27 seal bearers from a corpus of 80 seal bearers (on seals and bullae). The distribution has an average of 4.7, a mode (peak value) of 4, a median of 5, a standard deviation of 2.11, and a 95th percentile of 8. The corresponding value for stamped handles (5) is shown in red. The probability of attaining such a high (or higher) value among seals and bullae (0.002%) is indicated in the lower right corner.

Table 4. Summary of our statistical experiment comparing the number of first-name matches (homonyms), patronym matches (potential siblings), and cross-matches (potential genealogical relations) among stamped handles, on the one hand, and seals and bullae, on the other hand. The last column refers to the probability that a randomly chosen set of 27 seal-bearers (among seals and bullae) reaches a value as large (or larger) than the stamped handles. The results show a high statistical significance of the number of cross-matches.

	Handles	**Seals and bullae (average)**	**Seals and bullae (probability of matching the handles)**
First name matches	5	3.3	23.4%
Patronym matches	5	2.4	10.1%
Cross-matches	15	4.7	0.002%

4. Discussion

4.1. A genealogical interpretation of the name matches

Having established quantitatively that the number of name matches on stamped handles is exceptionally high, we now need to propose a qualitative explanation for this phenomenon.

A simple explanation would be that a restricted set of names was particularly popular among the Judahite elites that produced the private stamped handles. However, this explanation is unconvincing. If the recurring names were simply due to the popularity of a few names, we would also expect many more first-name and patronym matches. Our statistical experiment has shown, however, that, compared to seals and bullae, the number of name matches of either type is not exceptionally large, as both remain above the standard 5% probability threshold used in statistical testing. Any convincing explanation of the observed pattern needs to specifically account for the exceptionally high number of cross-matches (representing potential genealogical relations) on the handles.

In my view, the simplest explanation is that many of the *potential* genealogical relations are *real*, as suggested by Diringer. If so, the observed pattern simply illustrates the practice of passing down office (or craft) from father to son, a well-attested phenomenon in the Ancient Near East (Shirley 2005; 2013; Nielsen 2011; Jursa 2015; Favry 2016). One could object that our potential genealogical relations need not necessarily be genealogical. We called these relations *genealogical*, under the standard assumption that the second name occurring on each stamp represents the stamp bearer' s father, even when the filiation marker *bn*/*bt* ("son/daughter of") is not explicitly mentioned (*WSS*: 469–470; Lipschits 2021: 49).[14] Could the situation be different for the private jar-handle impressions? Indeed, the *bn*/*bt* filiation marker between the two consecutive names hardly ever occurs on private Judahite handle impressions but has been observed on ca. 55% of the seals and bullae featuring a patronym.[15] Could this indicate that we are dealing with a professional rather than genealogical relationship between the two names, as in the case of the stamped handles of *ʾlyqm nʿr ywkn* ("Elyaqim steward of Yokin"; *WSS* 663; see also Fox 2000: 182–191)? In that case, our observed pattern of potential genealogical relations would represent a pattern of inherited offices from upper-ranking to lower-ranking officials rather than from father to son.

While this interpretation is theoretically possible, the genealogical interpretation seems more likely, given the current state of our documentation. First, as noted above, it conforms to the standard interpretation of two consecutive

14 Only rarely has the second name on a seal been interpreted as other than a patronym. For example, Vainstub (2017) interpreted the second name on the seal of *šbnyhw ywʾb* from Tel ʿEton as a clan name rather than a patronym.

15 The statistics are based on the *Hebrew Stamp Seals* (*HSS*) online database (www.hebrewseals.com).

personal names in Hebrew glyptics. Second, this interpretation seems confirmed by *WSS* 688, the only private stamped handle in our corpus featuring a filiation mark. This handle reads *lnry bn šbnyh/šbnyw* and probably belongs to the same individual mentioned on handles *WSS* 686 and 687, which read *lnrʾ šbnʾ* without a filiation mark (see *WSS* 688; Vaughn 1999: 208–209, nos. XXIIa–XXXIIe). This identification implies that the direct concatenation of two personal names on a jar-handle impression, without a filiation mark, can indeed represent a genealogical relation. Furthermore, since handles *WSS* 686–688 do not significantly differ in layout or script from other private handles, the most natural hypothesis is that the other handles also assume a genealogical relation between the two consecutive names. Third, explicit titles expressing a non-genealogical relation between two private individuals (as opposed to royalty) are extremely rare in Hebrew glyptics; the case of *ʾlyqm nʿr ywkn* noted above is the only example of such a case among the provenanced Iron Age Hebrew seals and seal impressions. For all these reasons, I adopt the standard interpretation of the second name on the stamps as being a patronym. This, in turn, implies that the genealogical interpretation is the most likely explanation for the observed pattern of recurring names. However, the almost total absence of filiation marks among the handles remains striking (in contrast to their wide occurrence on seals and bullae) and can tentatively be explained by an idiosyncrasy of the private stamps' production milieu or by chronological anteriority of the handles (second half of the 8th century BCE) to many (possibly most) of the seals and bullae (late 7th–early 6th century BCE).

4.2. Updating Diringer' s genealogical tree

Figure 8 charts the 15 cross-matches (potential genealogical relations) attested by the stamped handles. These relations are indicated by dotted lines. Unlike standard genealogical trees, all the relations presented in this chart are strictly *potential* since a chance relation cannot be excluded.

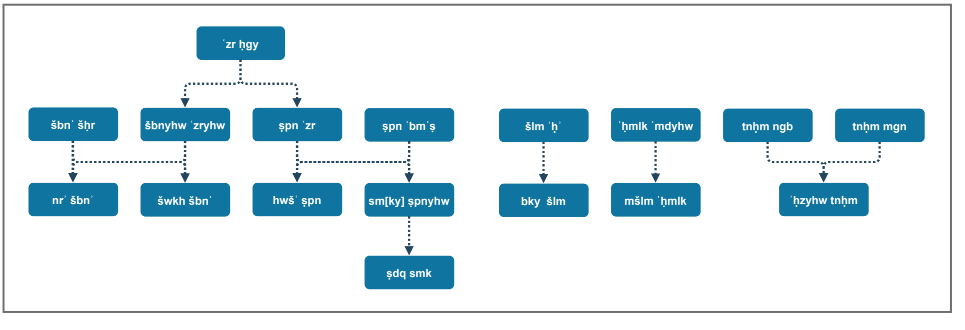

Fig. 8. A chart of 15 cross-matches (potential genealogical relations) among individuals named on private handle impressions. Each dotted arrow represents a potential genealogical relation (with arrows pointing from parent to child). For persons attested under variant names (say, *šbnyh ʿzryh* and *šbnyhw ʿzryhw*), only one variant is shown (see Table 1 for the full list of names).

Let us start with a few observations regarding the shape of the chart. Unlike Diringer's single tree (Fig. 1), our chart consists of four disjoint components: one large component comprising 10 persons and three small groupings comprising two to three individuals each. Of special interest is the large component, which is reminiscent of Diringer's tree and might represent an extended family. However, while Diringer's tree spanned up to eight generations, the current chart encompasses four at most.

We also note that five individuals have two incoming arrows, representing two potential fathers (e.g., *hwš' ṣpn* could be the son of *ṣpn 'bm'ṣ*, of *ṣpn 'zr*, or neither).[16] Since a person can have only one father,[17] at least five of these relations are random. Hence, the maximum number of real genealogical relations in our chart is 10 (i.e., 15-5). Interestingly, this number corresponds exactly to the difference between the observed number of cross-matches on the stamped handles (15) and the average number of cross-matches on seals and bullae (4.7 ≈ 5; see Table 4), underscoring that the existence of 10 real relations in our chart is plausible.

Having established that up to 10 relations in our chart are real, we would like to also obtain a result on the *minimum* number of real relations. Although some relations might be due to chance, it is improbable that *many* are. Indeed, our statistical experiment has shown that with a probability of at least 95%, seals and bullae feature at most eight name matches (Fig. 7). The observed excess of seven name matches on stamped handles (i.e., 15-8) therefore likely represents *real* genealogical relations, rather than random ones. The discussion below will, therefore, assume that at least seven of our potential genealogical relations are real.

Based on a choice of seven real genealogical relations, many different configurations of the genealogical chart are possible. On one extreme, one could have a single family comprising eight persons and spanning four generations (Fig. 9a).[18] On the other extreme, one could have up to seven disjoint families, each consisting of a single father-son pair, totaling 14 persons (Fig. 9b). Note, however, that with eight (or more) real relations, one could have up to eight single father-son pairs, totaling 16 persons (Fig. 9c). The total number of stamp-bearers involved in genealogical relations, therefore, ranges between eight and 16, which corresponds to 30% and 60% of our 27 stamp bearers.

16 These five cases are *nr' šbn'*, *šwkh šbn'*, *hwš' ṣpn*, *smk ṣpnyhw*, and *'ḥzyhw tnḥm*.

17 It is unlikely that a stamp bearer's both parents (father and mother) are represented, as this would mean that both parents had the same first name.

18 Note that the configuration of Fig. 9a closely resembles Diringer's genealogical tree: Its first three generations are included in his tree, except for *nr' šbn'* (see Fig. 1).

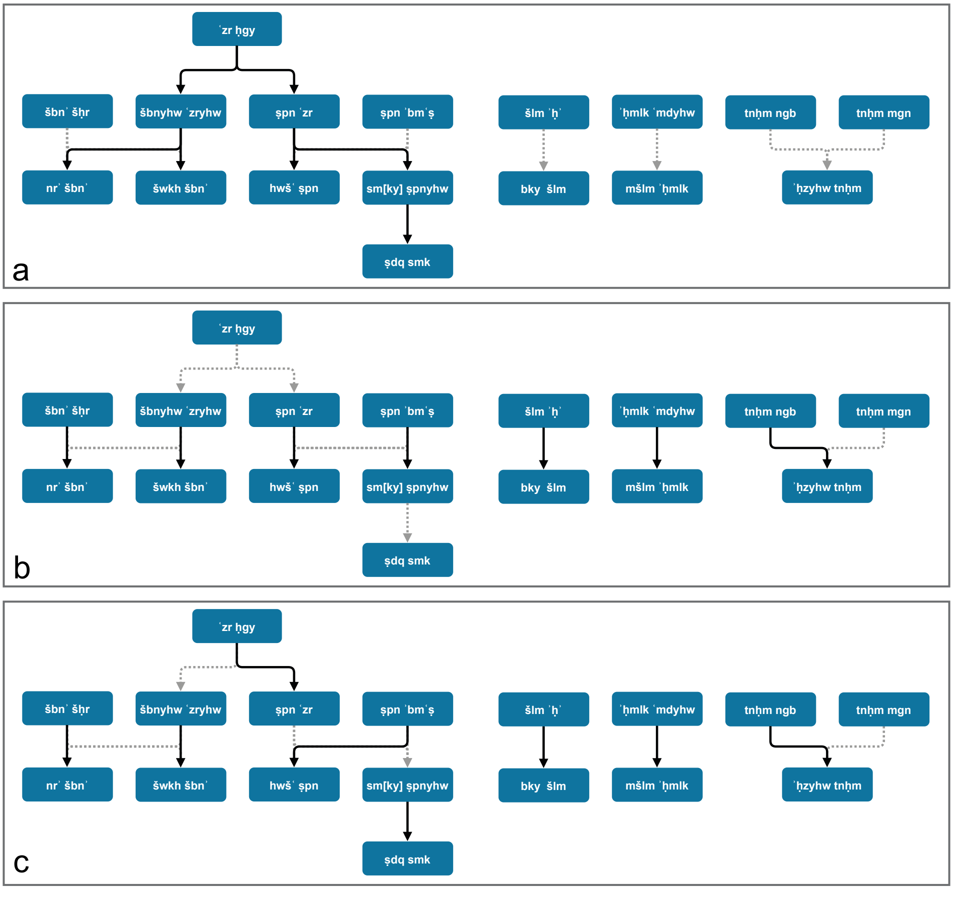

Fig. 9. Three realizations of the genealogical chart: (a) a single extended family of 8 individuals, spanning four generations; (b) seven disjoint father-son pairs, totaling 14 individuals; (c) eight disjoint father-son pairs, totaling 16 individuals. The first two configurations (a, b) use seven real relations, while the last (c) uses eight. Plain black arrows represent real genealogical relations, while dotted arrows represent random ones.

The final picture emerging from our genealogical chart is that rather than a single large family spanning six to eight generations, as proposed by Diringer (Fig. 1), we have a more modest scenario consisting of one to eight families, spanning two to four generations, and comprising eight to 16 people. Although modest, these observations suggest that the genealogical inheritance of a stamp bearer's office might have been common. Of course, future discoveries of yet unattested stamp bearers might manifest additional genealogical relations and refine this picture.

Note that these results do not necessarily imply that the stamps were used for a very long time. If the two-generation interpretation holds, the phenomenon might have lasted as little as two or three decades, since the stamping activity need not have covered the entire duration of both generations' offices, each of which might have been short (even possibly overlapping with the other). A longer duration is also possible, however, especially if we adopt a three- or four-generation interpretation of the genealogical chart.

5. Conclusion

This study has shown that compared to seals and bullae, the corpus of Judahite private jar-handle impressions features an exceptional pattern of recurring names. A closer look at these recurrences suggests that they derive from genealogical relations, spanning at least two generations and involving between 30% and 60% of the stamp bearers. These results quantitatively vindicate Diringer's qualitative intuitions from over 80 years ago. They imply that a stamp bearer's office was often inherited. Such practices of inherited titles, administrative functions, or crafts are well known in the Ancient Near East, and their occurrence on the Judahite private jar-handle impressions should, therefore, come as no surprise. However, Diringer's reconstructed genealogical tree, spanning six to eight generations (Fig. 1), was certainly too deep. Our alternative genealogical chart spans only two to four generations (Fig. 8).

Regarding chronology, the private Judahite stamped handles are often considered as related to military preparations in anticipation of the Assyrian invasion of Judah by Sennacherib and, hence, are thought to have operated only briefly before the 701 BCE invasion (Na'aman 1979; 1986; Lipschits, Sergi, and Koch 2010: 7; Ussishkin 2011: 236–237; Lipschits 2021: 106). Our results suggest that their duration might have been longer, possibly spanning several decades (for a recent high dating of the private stamps based on paleomagnetism, see also Vaknin et al. 2022: 5).

Another notable aspect is that most known private handles originate outside Jerusalem. Indeed, despite its importance as Judah's capital and the numerous archaeological excavations conducted therein, Jerusalem produced only 13 private stamped handles, fewer than Lachish (72 items), Ramat Raḥel (19 items), Beth Shemesh (18 items), and Mordot Arnona (17 items) (Sapir et al. 2023: Table 3). This suggests the possibility that the private handles were primarily a provincial phenomenon. By this token, one could consider the stamp bearers as provincial notables rather than officials of the centralized Jerusalemite administration. Insofar as provincial communities were possibly more conservative than the central elite in Jerusalem, this provincial affiliation might explain the observed profusion of kin relations among the stamp bearers. Note that Maeir and Shai (2022) recently concluded that the late Iron Age Judahite administration depended heavily on provincial, kinship-based components. The present study, showing a statistically high number of kinship relations among the stamp bearers, seems to reinforce these conclusions.

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Appendix: Details of the Statistical Experiment

A1. Data

A1.1. Names on stamped handles

1	’bm‘ṣ
2	’ḥ’/’ḥ’mr
3	’ḥzyhw
4	’ḥmlk
5	’lntn
6	’lšm‘
7	bky
8	hwš‘
9	hṣlyhw
10	zk’
11	ḥgy
12	ḥsd’
13	ḥšy
14	ybnh/yhwbnh/ywbnh
15	yhwḥl/yhwḥyl
16	yhwkl
17	yrmyhw
18	ksl’
19	mgn

20	mnḥm
21	mšlm
22	ngb
23	nḥm
24	nr’/nry
25	sm[k]/sm[ky]
26	‘bdy
27	‘zr/‘zryh/‘zryhw
28	‘mdyhw
29	ṣdq
30	ṣmḥ
31	ṣpn/ṣpnyhw
32	rp’y
33	šbn’/šbnyh/šbnyhw
34	šwkh
35	šḥr
36	šlm
37	tnḥm

A1.2. The handles.csv file

Contents of the CSV file comprising the first names (PN1) and patronyms (PN2) of the stamped handles corpus. The numbers correspond to the names in Table A1.1 above.

PN1	PN2
3	37
4	28
7	36
8	31
12	17
13	6
15	35
18	10
20	14
21	4
21	5
23	9
23	26
24	33
25	31
27	11
29	25
30	6
31	1
31	27
32	16
33	35
33	27
34	33
36	2
37	19
37	22

A1.3. Names on seals and bullae

1	’whl
2	’wš’
3	’ḥ’
4	’ḥ’b/’ḥy’b
5	’ḥ’mh
6	’ḥz
7	’ḥyhw
8	’ḥymh
9	’ḥmlk
10	’kr
11	’l’r
12	’lyhw
13	’lyqm
14	’lyrmh
15	’lyš‘
16	’lyšb
17	’lntn
18	’lšm‘
19	’mryhw
20	’prḥ
21	’ryhw
22	’šyhw
23	blgy
24	bnyhw
25	b‘d’l
26	brkyhw
27	g’l
28	gdyhw
29	gdlyhw
30	gmryhw
31	dlyhw
32	dmlyhw
33	hdyhw

34	hwš‘yhw
35	ḥgy
36	ḥzqyhw
37	ḥlṣyhw
38	ḥlqyhw
39	ḥmy’hl
40	ḥnmlk
41	ḥnnyh/ḥnnyhw
42	ḥṣy
43	ṭbš
44	ṭbšlm
45	y’wš/y’š
46	y’znyhw/y’zny
47	yd‘yhw
48	yhw’b
49	yhw’l
50	yhwhḥn
51	yhwzrḥ
52	yhwḥy
53	yhwkl
54	yqmyhw
55	yrḥm’l
56	yrmyhw
57	yš’l
58	yšm‘’l
59	yš‘yhw
60	klkl
61	knyhw
62	m’syhw/m’s
63	mgn
64	mḥsyhw
65	my’mn
66	mk’ḥ

67	mkyhw/mk’
68	mlky/mlkyhw
69	mnḥm
70	m‘šyhw
71	mqnyhw
72	mšlm
73	mtnyhw
74	nḥm
75	nryhw
76	ntnyhw
77	sl’/slw’
78	smkyhw/smk
79	s‘ryhw
80	‘dyhw
81	‘zryhw/‘zr
82	‘zrqm
83	‘lyhw
84	‘lyhnh
85	‘myḥy
86	‘nnyhw
87	‘šyhw
88	plṭyhw
89	pq‘t
90	pšḥwr
91	ṣpn/ṣpnyhw/ṣpnyh
92	rp’yhw
93	š’lh
94	šbnh/šbnyhw
95	šlm/šlmyhw
96	šm‘yhw
97	špṭyhw
98	špn

A1.4. The seals-bullae.csv file

Contents of the CSV file comprising the the first names (PN1) and patronyms (PN2) of the seals and bullae corpus. The numbers correspond to the names in Table A1.3 above.

PN1	PN2
4	25
5	83
4	48
4	69
8	41
9	78
10	73
12	11
16	22
13	1
13	51
13	67
15	45
17	23
18	78
20	7
21	81
23	31
24	34
26	68
28	81
29	90
30	63
30	98
31	29
31	34
35	57

PN1	PN2
35	94
36	6
38	62
39	69
40	58
41	3
41	43
44	53
46	70
47	2
47	72
49	65
50	89
53	9
53	52
53	95
54	37
55	74
56	91
58	75
59	19
61	33
62	13
66	85
67	42
72	71
73	58

PN1	PN2
73	81
74	86
74	93
75	32
76	45
77	14
79	94
80	9
80	59
81	38
82	67
84	27
92	20
92	91
92	95
93	72
94	4
94	78
95	60
96	46
96	64
96	88
97	32
97	78
97	87
97	91

A2. Python source code

```
import numpy as np, random, statistics
from matplotlib import pyplot as plt

n = 80 # Number of bearers of seals and bullae
m = 27 # Number of bearers of private jar-stamps
k = 100000 # Number of samples of size k among the set of size n
(seals&bullae)
ENFORCE_DIFFERENT_SUBSETS = False # Use False for a faster
enumeration.
SEALS_BULLAE_FILE = 'seals-bullae.csv'
HANDLES_FILE = 'handles.csv'

def random_combination(iterable, r):
 "Random selection from itertools.combinations(iterable, r)"
 pool = tuple(iterable)
 n = len(pool)
 indices = sorted(random.sample(range(n), r))
 return tuple(pool[i] for i in indices)

def take_subset(data, subset_indexes):
 return [data[i] for i in subset_indexes]

def read_data(filename):
 all_pairs = []
 f = open(filename,'r')
 for line in f.readlines():
  line = line.rstrip()
  (a,b) = line.split(',')
  all_pairs.append((a,b))
 return all_pairs

# Number of repeated names
def count_nbr_repeated_names(comb):
 repeated_names = []
 for i in range(0, len(comb)) :
  for j in range(i+1, len(comb)):
   seal1 = comb[i]
   seal2 = comb[j]
   if seal1[0] == seal2[0] or seal1[0] == seal2[1] :
    repeated_names.append(seal1[0])
   elif seal1[1] == seal2[0] or seal1[1] == seal2[1]:
    repeated_names.append(seal1[1])
 return len(set(repeated_names))

#Number of persons with repeated names
def count_persons_with_rep_names(comb):
 persons = []
 for i in range(0, len(comb)) :
  for j in range(i+1, len(comb)):
   seal1 = comb[i]
   seal2 = comb[j]
   if seal1[0] == seal2[0] or seal1[0] == seal2[1] or \
    seal1[1] == seal2[0] or seal1[1] == seal2[1]:
    if not i in persons:
     persons.append(i)
    if not j in persons:
```

```
    persons.append(j)
 return len(persons)

# Number of repeated pairs (PN1=PN1 or PN2=PN2 or PN1=PN2 or
PN2=PN1)
def count_repeated_pairs(comb):
 count = 0
 for i in range(0, len(comb)) :
  for j in range(i+1, len(comb)):
   seal1 = comb[i]
   seal2 = comb[j]
   if seal1[0] == seal2[0] or seal1[0] == seal2[1] or \
    seal1[1] == seal2[0] or seal1[1] == seal2[1]:
    count = count+1
 return count

# Number of homonyms (PN1=PN1)
def count_homonyms(comb):
 count = 0
 for i in range(0, len(comb)):
  for j in range(i+1, len(comb)):
   seal1 = comb[i]
   seal2 = comb[j]
   if seal1[0] == seal2[0]:
    count = count+1
 return count

# Number of potential siblings (PN2=PN2)
def count_potential_siblings(comb):
 count = 0
 for i in range(0, len(comb)):
  for j in range(i+1, len(comb)):
   seal1 = comb[i]
   seal2 = comb[j]
   if seal1[1] == seal2[1]:
    count = count+1
 return count

# Number of potential father-son relations (PN1=PN2 or PN2=PN1)
def count_potential_genealogical_relations(comb):
 count = 0
 for i in range(0, len(comb)) :
  for j in range(i+1, len(comb)):
   seal1 = comb[i]
   seal2 = comb[j]
   if seal1[0] == seal2[1] or seal1[1] == seal2[0]:
    count = count+1
 return count

def print_plot(data, n, m, k, target, xlabel):
 LABEL_OFFSET = 3
 bins = np.arange(-100, 100, 1) # fixed bin size
 if(len(data) >0) :
  plt.xlim([min(data)-5, max(data)+5])
 plt.hist(data, bins=bins, alpha=1, label = "seals and bullae")
 plt.title(str(int(k/1000)) +'K random subsets of '+ str(m) +
'seals among ' + str(n) + " seals")
 plt.xlabel(xlabel)
```

```
 plt.ylabel('Count')
 plt.axvline(x = target, color = 'r', label="handles")
 plt.plot([target, max(data)+5], [0, 0], color="red", lw=3,
    linestyle='solid', label="_not in legend")
 plt.annotate(str(round(count_geq(data, target)/k*100,4))+"%",
     xy=(target+(max(data)+5-target)/2,
      data.count(statistics.mode(data))*0.02),
     xytext=(0, 0), color="red",
     textcoords="offset pixels")
 plt.annotate(str(target),
     xy=(target, data.count(statistics.mode(data))*0.75),
     xytext=(LABEL_OFFSET, 0), color="red",
     textcoords="offset pixels")
 plt.legend()
 plt.show()

def print_results(data, n, m, k, target, xlabel):
 if(len(data) > 0) :
  print("Stamped handles value:", target)
  print("Seals & bullae values: ", end="")
  print("min=", min(data),
    ", max=", max(data),
    ", mode=", statistics.mode(data),
    ", median=", round(statistics.median(data), 2),
    ", mean=", round(statistics.mean(data), 2),
    ", std-dev=", round(statistics.stdev(data), 2),
    ", 95th percentile=", np.percentile(data, 95),
    sep="")
 print_plot(data, n, m, k, target, xlabel)
 print()

# Choose k random uniform subsets of size m among the set [0, ...,
n-1].
# Boolean parameter "different" enforces choice of different
subsets, if True.
def get_random_indexes(n, m, k, different):
 samples = 0
 all_combs = []
 while samples < k:
  comb = random_combination(range(n), m)
  if different and comb in all_combs:
   print("Already chosen")
  else:
   samples = samples+1
   all_combs.append(comb)
   if samples % 10000 == 0:
    print("\t", int(samples/1000), "/",int(k/1000), "k", sep='')
 return all_combs

def get_random_subsets(data, random_indexes):
 result = []
 for elem in random_indexes:
  result.append(take_subset(data, elem))
 return result

def count_geq(l, x): # number of elements in list l that are greater
or equal to x
 return len([i for i in l if i >= x])
```

```
def apply(func, handles, subsets, title):
 print(title)
 for i in range(len(title)):
  print("=", end="")
 print()
 count = func(handles)
 data =[func(elem) for elem in subsets]
 print_results(data, n, m, k, count, title)

handles = read_data(HANDLES_FILE)
seals_bullae_data = read_data(SEALS_BULLAE_FILE)
print("Generating ", int(k/1000), "K subsets....", sep='')
random_indexes = get_random_indexes(n, m, k, ENFORCE_DIFFERENT_
SUBSETS)
subsets = get_random_subsets(seals_bullae_data, random_indexes)
print("...done.\n")

apply(count_nbr_repeated_names, handles, subsets, "Number of
recurring names")
apply(count_persons_with_rep_names, handles, subsets,
  "Number of persons with recurring names")
apply(count_repeated_pairs, handles, subsets, "Number of name
matches")
apply(count_homonyms, handles, subsets, "Number of first name
matches")
apply(count_potential_siblings, handles, subsets,
  "Number of patronym matches")
apply(count_potential_genealogical_relations, handles, subsets,
  "Number of cross-matches")
```