The Royal Judahite Storage Jar: A Computer-Generated Typology and Its Archaeological and Historical Implications

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The paper presents an objective, repeatable and independent computer-generated typology of the Iron Age II Oval Storage Jar (OSJ), also known as the lmlk or Royal Judahite Storage Jar. It demonstrates that this jar was in use from the late 9th to the early 6th century BCE and that it was distributed beyond the confines of the Judahite administrative system. The OSJ first appeared as a local phenomenon that was limited to the Shephelah, with no particular political or ethnic affiliation. During the early to mid-8th century BCE, the production of some of the jars became standardized, which is evidence of the consolidation of the Kingdom of Judah and its territorial expansion into the lowlands region. By the late 8th century BCE, at least one or more of the workshops producing these jars became integrated into the royal Judahite administrative system that stamped jar handles, and this established the workshop’s main function until the destruction of Judah in the early 6th century BCE.

KEYWORDS Kingdom of Judah, Judahite Storage Jars, lmlk stamped handles, Shephelah, Computer-generated typology

The study of the Judahite Oval Storage Jar (OSJ), commonly known as lmlk or Royal Judahite Storage Jar, has been at the heart of archaeological and historical research of Iron Age Judah (see, e.g., Tuffnel 1953: 312–316; Ussishkin 1977: 56–57; 2004: 2141–2142; Na’aman 1979; 1986; Vaughn 1999: 81–169). Since many of these jars were sealed in destruction levels well dated to Sennacherib’s 701 BCE campaign, especially at Lachish Level III (Tuffnell 1953: 315–316; Zimhoni 2004), they have become a marker of the late 8th century BCE material culture in Judah. And as some of the handles of these jars
bear *lmlk* and ‘private’ stamp impressions (Ussishkin 1976; 2004: 2133–2147; Na’aman 1979; 1986; Vaughn 1999: 81–109; Kletter 2002; Lipschits, Sergi and Koch 2010; 2011), they have been associated with the royal administrative and economic system of the Kingdom of Judah.

Historical pre-positions regarding the OSJ’s role in the administration and economy of Judah overshadowed the issues of morphology of the vessels and their stratigraphic provenance. Two facts call for a fresh look at the typology of the jars, their stratigraphy and their chronology:

(1) Similar unstamped jars were found in strata dating up to 150 years earlier than the Lachish III destruction, such as Arad Stratum X, Gezer Level VIA, Tell eṣ-Ṣâfi/Gath Level A3 and Beth-Shemesh Level 3.

(2) Some of the places where OSJ were found are located outside the borders of Judah.

The aim of this paper is to present an objective, repeatable and as far as possible independent computer-generated typology for the OSJ (Karasik and Smilansky 2008; 2011).

### History of research

#### Chronology

The large number of stamped and unstamped OSJ found at Lachish turned it into a key site for understanding their chronology. Tufnell (1953: 315–316) stated that all the jars were confined to the destruction of Level III, which was attributed by her to Sennacherib’s 701 BCE campaign, a date confirmed by the renewed excavations at the site (Ussishkin 1977: 54–57; 2004: 2141–2142). Ussishkin accepted Na’aman’s historical reconstruction (1979; 1986), which connected the production of the jars and the system of the stamp impressions to Hezekiah’s preparations in advance of the Assyrian onslaught. Evidence that oval jars similar to the ones at Lachish were found in strata dating earlier than Lachish III appeared at Arad (Aharoni and Aharoni 1976: 83) Gezer (Gitin 1990: 122–124) Tel Batash (Mazar and Panitz Cohen 2001: 93–94, Pl. 81: 9–10, 83: 2, 21; 86: 12) and Tell eṣ-Ṣâfi/Gat (Shai and Maeir 2003: 109–110). As for the latest date for the use and manufacture of the royal Judahite storage jars, items that are similar in shape and clay composition were found both at Lachish Level II and at Tel Batash Stratum II (Zimhoni 2004: 1799–1800 and Fig. 26.44: 1–2; Mazar and Panitz Cohen 2001: 95–96, Pl. 35: 1–3, 46: 1, 3, 4, 6–7, 9–10). Lipschits, Sergi and Koch (2010, 2011) have recently suggested a new chronological scheme for the *lmlk* stamped jars, dividing between “early types”, used before the 701 BCE Assyrian attack, and “late types”, dated to the beginning of the 7th century BCE (Lipschits, Sergi and Koch 2010: 11, 13–17, and Fig. 1; see Ussishkin’s rejoinder [2011] and Lipschits’ counter response [2012]). They further suggested that the *lmlk* system was part of a long-term bureaucratic apparatus in Judah, which was introduced before Hezekiah’s revolt, and was replaced by the system of incised concentric circles (dated to the mid-7th century BCE) and the rosette stamp impressions (dated to the end of the 7th and to the early 6th centuries BCE).

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1 As already noted by Vaughn (1999: 138–140).
Typology
Tufnell (1953: 315–316) was the first to notice the standardized form and the distinctive clay material of the OSJ found at Lachish. Zimhoni (2004: 1794–1795) classified two main types of jars that she labelled *lmlk* jars (stamped or unstampeed), and *lmlk*-like jars (unstamped). Zimhoni hypothesized that the differences between the two types can be explained by the existence of distinct workshops. Shai and Maeir (2003) suggested identifying the OSJ found in strata dating earlier than Lachish III as predecessors of the *lmlk* jars and labelled them “pre-*lmlk* jars”. Gitin (2006) accepted Mazar and Panitz-Cohen’s conclusion (2001: 97) that the rosette jars were inspired by the so-called *lmlk* jar, and thus was the first to include in the typological analysis jars with similar shape but with a more elongated oval body that were found at various sites concurrent with Lachish Level II (late 7th–early 6th century BCE), some of which bore rosette impressions on their handles. Gitin indicated that the OSJ represent a long and continuous Judahite pottery tradition and rejected the term *lmlk* jars, which implies that all these jars took part in the royal Judahite administrative system. He suggested using a more technical name, Oval Judahite Jars, which he divided into six sub-types, manufactured in Judah between the 9th and the 6th centuries BCE.

Capacity, uniformity and function
The question of dimensions garnered a great deal of attention from the time Cross (1969) hypothesized that the stamped handles were a guarantee of capacity. Ussishkin (2004: 2145) measured the volume of ten complete restored *lmlk* jars from Lachish and found a difference of 12.05 litres between the smallest (39.75 litres) and largest (51.80 litres) jars. He concluded that the data hardly support the suggestion that the royal stamp impression guaranteed a certain capacity and that the royal Judahite administrative system did not have exact and unified weights and measures.

Zapassky, Finkelstein and Benenson (2009) assumed that the Judahite bureaucrats aimed at standardizing the volume of the *lmlk* jars. Since the potters did not pay attention to the dimensions of the vessels (that vary up to 10.4% in their size and volume), they developed a sophisticated calculation method in order to verify the volume of the jars. Lipschits et al. (2011) demonstrated that the need for accuracy in liquid measures is a reflection of a modern concept, which has no basis in the reality of the ancient world (and cf. Powell 1990: 899–900; Kletter 2009: 361–62). The reality, based on biblical descriptions and the actual finds, was that hundreds of *lmlk* jars were used in the administrative system in order to store agricultural commodities and the average volume of these jars balanced

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2 For the *lmlk* jars, see Zimhoni 2004, Group III: SJ-1, Figs. 26.6, 26.7, 26.8: 1, 3 and for the *lmlk*-like jars see idem., Group III SJ-2: Figs. 26.8: 4–8, 26.9, 26.10: 1–3. According to Zimhoni, the difference between the two types is in the clay from which the *lmlk* jars (as opposed to the *lmlk*-like jars) were made: a well-fired, reddish-brown clay with white grits that differs from the other Lachish Level III vessels, assuring their identification even when they bear no impressions (see also Freud 1999: 206–208; Mazar and Panitz-Cohen 2001: 93–94).

3 It seems, however, that Zimhoni’s characteristics do not hold when applied to large assemblages of jars, or jars from sites other than Lachish (Mazar and Panitz-Cohen 2001: 94; Gitin 2006: 508–509); therefore, the fabric is not a good criterion for a typological classification of the jars.
the inaccuracy of the system. Lipschits et al. further argued that in Iron Age Judah, like at other places in the ancient Near East, there were liquid units but not volume measurements. The Judahite lmlk storage jar was the basic container for liquids in Judah, and it can be identified with the biblical bath.

The question thus arises: was accurate measurement important to the royal Judahite administrative system? In order to reach a better understanding of the role of the OSJ in this system, a large number of jars must be measured and analyzed according to their typological and chronological distribution.

Place of production

Amiran and Vroman (1946: 13–15) applied heavy mineral analysis (analysis of particles within a sediment, having the specific gravity of above 2.8) to lmlk stamped handles and concluded that there was more than one production centre. Later spectrograph analyses of larger numbers of lmlk jars revealed that the jars with handles mentioning all four places (Hebron, Socoh, Ziph, and mmšt) were sufficiently chemically similar to suggest that their clay originated from the same clay bed (Millett et al. 1964). The most important studies of the lmlk storage jars used Instrumental Neutron Activation Analysis (INAA). They showed that all the lmlk jars had been made in one specific location, somewhere in the Shephelah, except for two pithoi bearing lmlk stamp impressions that were made from clay of the Moza Formation from the Jerusalem area (Mommsen, Yellin and Pearlman 1984; Gunneweg et al. 1985: 272–278; Yellin and Cahill 2003; 2004). Goren and Halperin (2004) took this conclusion a step further. They conducted an optical mineralogy study on a collection of lmlk storage jars from Lachish and Beth-Shemesh, and were able to demonstrate petrographically that the clay originated in the Valley of Elah or its vicinity, proposing the site of Socoh as a probable place of origin for the entire group. Rosette stamped handles were subjected to INAA, which proved that most of the vessels were made of the same clay as the lmlk jars, while some were made of a different clay from the Jerusalem area (Mommsen, Perlman and Yellin 1984: 106–107; Yellin and Cahill 2003). This notion further supported the view that the rosette jars continue the tradition of the lmlk jars.

Theoretical and methodological background

The current study used 3-D computerized models to accurately measure morphological features of large numbers of OSJ. It thus offers not only a non-biased typological analysis but also the possibility of examining features such as capacity and standardization, which are crucial for understanding the administrative system behind the vessels.

A fundamental principle in our approach is that typological analysis should be entirely independent and repeatable. This notion is critical, since in many cases the stratigraphical context, the provenance or the manual drawing of a jar may bias comparison, even unconsciously. Therefore, we chose to adopt automatic methods for the data acquisition of the profiles (Karasik and Smilansky 2008) and for its morphological classification (Karasik and Smilansky 2011).

The shape of each jar was captured using a structured light scanner that produces high resolution 3D models. The correct orientation of the models was then automatically
computed to enable an independent and accurate measurement of the cross-section profile of the jar (Karasik and Smilansky 2008). The extracted profiles are the raw data for the following step—computerized typology and classification of ceramic shapes (Karasik and Smilansky 2011). In this method the cross-section profiles are considered as curves in the plane, which are represented by three mathematical functions: the radius, the tangent and the curvature (Gilboa et al. 2004; Adan-Bayewitz et al. 2009; Karasik and Smilansky 2011). Mathematically speaking, each of the three representations of the profile stores the entire morphological information of the curve. They differ, however, in the sort and scale of features to which they are most sensitive. The classification is based on the ability to quantify the distance between shapes of different vessels. This is accomplished by computing the differences between the corresponding mathematical representations. The numeric results for the complete assemblage are summarized in a table that is called the ‘distance matrix’. Next, we applied several statistical methods (e.g., Principal Component Analysis, Cluster Analysis and Discriminant Analysis) in order to analyze the structure of the assemblage and to reveal inner grouping and sub-types (ibid.).

A powerful output of the classification method is a self-explanatory cluster tree, which provides a hierarchical method for simultaneously investigating grouping in the data over various scales (Aldenderfer and Blashfield 1978; 1984). The cluster tree is a convenient tool for exploring and visualizing correlations in a data set (see Fig. 1). Every line at the bottom of the tree represents one jar, and the various leaves are connected to branches that are connected to lower branches and so on, until the root of the tree is reached. The algorithm that constructs the tree places similar objects on the same branch (cluster) and each branch represents a segregated morphological group. Our typology was generated based on these segregated clusters and each of them was defined as a sub-type of the OSJ (Karasik and Smilansky 2011). Only after the computerized automatic and objective classification was complete did we compare the provenance information, the chronology and the stamp impressions in each sub-type. The resulting clustering correlates well with the chronological data and the stamping system (below).

The automatic classification and clustering is based on the entire morphology of the jar’s upper part. Every point along the profile contributes to the final distance value between two profiles. After the construction of the cluster tree and the definition of the groups, the main characteristics of the shape of each group are recorded. This includes the average values of features such as the length of the neck and its angle, the width of the shoulder, etc. (see Figs. 2a–d). This method differs from traditional methods, where the attributes are defined first and the typology is then built based only on several measurements. We wish to emphasize, however, that the computerized classification is not based directly on these parameters. Rather, it takes into account the complete shape of the objects, from small-scale details using the curvature function through to medium size features with the tangent function and up to the large components with the radius representation (Karasik and Smilansky 2011).
The assemblage

One hundred and ten vessels that qualify as OSJ were collected and 3D-scanned. Since analysis was based on the shape of the upper half of the profile, only complete or almost-complete jars were included. Table 1 presents the provenance of the scanned jars.

<table>
<thead>
<tr>
<th>Site</th>
<th>Number of Jars</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tell eṣ-Ṣāfi</td>
<td>10</td>
</tr>
<tr>
<td>Gezer</td>
<td>11</td>
</tr>
<tr>
<td>Beth-Shemesh</td>
<td>8</td>
</tr>
<tr>
<td>Lachish</td>
<td>36</td>
</tr>
<tr>
<td>Tel ʿIra</td>
<td>12</td>
</tr>
<tr>
<td>Tel Batash</td>
<td>9</td>
</tr>
<tr>
<td>Arad</td>
<td>7</td>
</tr>
<tr>
<td>Beer-sheba</td>
<td>2</td>
</tr>
<tr>
<td>ʿEin Gedi</td>
<td>4</td>
</tr>
<tr>
<td>Jerusalem City of David</td>
<td>7</td>
</tr>
<tr>
<td>Tel Malḥata</td>
<td>2</td>
</tr>
<tr>
<td>Horvat Titora</td>
<td>1</td>
</tr>
<tr>
<td>Unknown</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>110</strong></td>
</tr>
</tbody>
</table>

Results

Computer-generated classification of the OSJ

Figure 1 shows the main cluster tree for the classification of the OSJ. Branches of this tree were defined in our typology as sub-types of the jars. The indices of these branches, as marked on the figure, are arbitrary and have no significance.

![Cluster Tree Diagram](image)

**Figure 1** The cluster tree for the complete assemblage of OSJ in this study.
Based on the cluster tree, we have defined four main branches and seven sub-types of jars. Their morphological characteristics include height of neck, neck orientation, maximal radius and vertical distance from the rim at the widest point. These are summarized in Fig. 2a–d. The results demonstrate that the parameter values of the sub-types have different patterns and distributions, as shown in Fig. 2. The figures show the average values of the parameters and their standard deviations.

Figure 2a–d Several morphological parameters that were measured for each sub-type.

In addition to the cluster tree, another convenient and concise method to investigate grouping in the data is by using Principal Component Analysis (PCA, see Jackson 1991; Jolliffe 2002). This method transfers the original information from the distance matrix into a set of components, with no loss of information. These parameters are independent and have a descending magnitude of variability. The spread of the sub-types in the plane of the principal components can serve as an indication of their uniformity and homogeneity. Usually, only a few parameters suffice to represent most of the variability that exists in the assemblage. Figure 3 shows the distribution of the first three principal components (with relative variability of 56%, 20% and 9%, respectively). What captures the eye first is the complete dichotomy in PCA 1 between Group 4 and the rest of the assemblage. This emphasizes that the small jars with only two handles belong to a different morphological world. Other trends are more difficult to follow and one should always check the distribution of the groups in all leading components. In the current study, the first three parameters that are shown in Fig. 3 represent more than 85% of the entire variability in the assemblage. It is difficult and most of the time also irrelevant to identify the principal components with a specific shape parameter such as the parameters in Fig. 2. Nevertheless, the spread of the sub-types in the plane of the principal components can serve as an indication for their
uniformity and homogeneity. These parameters are necessary in order to better understand the suggested typology of the jars, but they also carry some historical implications, as the uniformity and standardization of jars may have some bearing on their production and use. Figure 4 displays three different measurements that express the inner uniformity and standardization of each sub-type. Two of them were measured by the PCA analysis.

**Figure 3** The distribution of the jars according to their three principal components. The x-axis corresponds to PCA (Principal Component Analysis) 1 and the y-axis is divided between PCA 2 (bottom) and PCA 3 (top).

**Figure 4** Three measurements that express homogeneity within the sub-types: (a) the average distance between members of the same sub-type; (b) the sum of standard deviations for the first three principal components; (c) the sum of the ranges of the first three principal components normalized by the size of the groups.
(b and c), and one of them was measured directly from the distance matrix (a). Low values in Fig. 4 correspond to a high standardization level of the sub-type.

The capacity of the jars is another important parameter that can be easily measured directly from the 3D model. However, the computed volume is not the net capacity since it includes the body of the jars. Figure 5 shows the average volumes and standard deviations for the sub-types.

Based on this clustering we offer the following typology.

**Branch 1**

**Sub-type 1a (Fig. 6)**

Twenty-five jars were clustered as Sub-type 1a. These jars are typified by a pear-shaped body with a slanted shoulder and a slightly inclined (ca. 110 degree) medium-size neck (ca. 5 mm long). Jars of this sub-type are relatively large as their average maximal radius is 215 mm and the distance between their rims and widest point is close to 200 mm. Their volume varies between 50 and 60 litres. Sub-type 1a is the most uniform sub-type, as can be seen in Fig. 4. This is even more impressive when one considers that it is the largest sub-type. Table 2 presents the distribution of the jars.

**Sub-type 1b (Fig. 7)**

Twenty-two jars were clustered as Sub-type 1b. Sub-types 1a and 1b are morphologically close to each other. However, Sub-type 1b jars have a slightly more horizontal shoulder and their average maximal radius is smaller, resulting in a lower capacity that fluctuates...
between 45 and 55 litres. Like Sub-type 1a, these jars also form one of the most uniform sub-types (Fig. 4). It should be noted that two jars with somewhat different morphological features were grouped into this sub-type as well. One of them, from Tel Malḥata, has only two handles (one of them stamped with a rosette stamp impression) and its shape is unparalleled in the assemblage. The other one is from the City of David; its upper part shows more similarity to this sub-type than to the one from Tel Malḥata. Table 3 presents the distribution of the jars.

**Branch 2**

**Sub-type 2a (Figure 8)**

Eight jars were clustered as Sub-type 2a. The type has a pear-shaped body with a sharply-inclined (ca. 120 degree) medium-size neck (ca. 4 cm). Its maximal radius averages 185 mm and the maximal vertical distance between the rim and the widest point averages 175 mm. These measurements make the jars of Sub-type 2a smaller than the jars of Sub-types 1a and 1b. Some of the jars of this sub-type have only two handles, but they are much larger than most of the two-handled jars clustered in Branch 4.

Sub-type 2a corresponds to very few jars with a combination of qualities that also fit other sub-types. The computerized classification averages all morphological information; Branch 2 is probably closest in shape to these jars. Even so, they belong to a separate sub-type that may represent outliers or irregular jars. Table 4 summarizes the provenance of these jars.

**Sub-type 2b (Fig. 9)**

Sixteen jars were clustered as Sub-type 2b. These jars are typified by an elongated body as is made apparent by the distance between their rim and widest point, which is close to 240 mm. The shoulder is slanted and the neck is short (3 cm) and vertical (ca. 90 degrees). Jars of this sub-type are relatively large as their average maximal radius is 200 mm and their volume fluctuates between 44 and 52 litres, with relatively low standard deviations. This is a very uniform type both in terms of morphology of profile and volume. Table 5 summarizes the distribution of these jars.

**Branch 3**

**Sub-types 3a, 3b, 3c**

Analyzing Branch 3 together with a thorough examination of the parameters displayed in Fig. 2 may raise the question: why does Sub-type 3c cluster together with Sub-types 3a and 3b, while its distribution in Fig. 2 is always different from that of Sub-types 3a and 3b.

There are two parts to the answer: First, as has already been stressed, the complete shape is much more complex than expressed by the four parameters that were examined in this research. Second, only four jars belong to Sub-type 3c, and the sizeable standard deviations testify that these jars are not similar to each other. Every one of them has only one or two features that are similar to others in Branch 3. Thus, Branch 3 is the closest branch for them to be in but only as a separate sub-type with very low uniformity. Therefore, we see Sub-types 3a and 3b as the main part of the group while Sub-type 3c corresponds
to the irregular examples and thus will not be considered in the following archaeological and historical discussion. Moreover, three out of the four jars in this sub-type are broken and their profiles do not have the maximal share that was included in the classification (see Fig. 12). The fourth jar is highly deformed and its comparison was probably biased.

Sub-type 3a (Fig. 10)
Eight jars were clustered as Sub-type 3a. They are typified by a pear-shaped body. The shoulder is relatively horizontal and the neck is long (5–6 cm) and inclined (ca. 110 degrees). Their average maximal radius is 195 mm and their volume fluctuates between 37 and 50 litres. Jars clustered as Sub-type 3a are less uniform compared to jars clustered as Sub-types 1a, 1b and 2b, and they have an extensive range of capacity values (37–51 litres). Table 6 presents the provenance of these jars.

Sub-type 3b (Fig. 11)
Eleven jars were clustered as Sub-type 3b. These jars are similar to the jars of Sub-type 3a as they have a slight incline (ca. 110 degrees) and high neck (ca. 4–6 cm long). However, there is a clear division between Sub-types 3a and 3b in terms of their body shape and size. Sub-type 3b jars are typified by a rounded (as opposed to carinated) body with a slanted shoulder. The maximal radius (ca. 220 mm) and capacity (between 55 to 67 litres) of Sub-type 3b jars are much larger than all other sub-types (see Figs. 2c and 5). Table 7 presents their provenance.

Branch 4 (Figure 13)
Thirteen jars were clustered as Branch 4. These are small jars with low capacity compared to other OSJ; they are distinct from the rest of the assemblage and have only two handles. These jars were included as a control group. Their distinction from the rest of the assemblage can be seen in the PCA analysis (Fig. 3), which shows that they are part of a different morphological world. The jars cluster into at least two sub-types but we avoided further typological analysis as they probably do not form a part of the OSJ phenomenon, nor were they part of the royal administrative system in Judah.
Figure 6  Representative examples, Sub-type 1a: (1) Registration number 10250/1 L4001, Lachish III (Zimhoni 2004: Fig. 26.13: 6); (2) Registration number 10075/1 L4014, Lachish III, (Zimhoni 2004: Fig. 26.6: 4)

Table 2: Provenance of Sub-type 1a

<table>
<thead>
<tr>
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<th>Site</th>
<th>Stratum/level</th>
<th>Comment</th>
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</thead>
<tbody>
<tr>
<td>14</td>
<td>Lachish</td>
<td>III</td>
<td>Four of the jars have <em>lmik</em> stamped handles and one has <em>lmik</em> and ‘private’ stamps impression.</td>
</tr>
<tr>
<td>3</td>
<td>Tel Batash</td>
<td>III</td>
<td>One jar has <em>lmik</em> stamped handle.</td>
</tr>
<tr>
<td>2</td>
<td>Tel ‘Ira</td>
<td>VII</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Tel ey-Ṣāfi</td>
<td>A3</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Beer-sheba</td>
<td>II</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Beth Shemesh</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Arad</td>
<td>?</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Gezer</td>
<td>VIA</td>
<td></td>
</tr>
</tbody>
</table>
Figure 7 Representative examples, Sub-type 1b: (1) Registration number 10613/1 L4014, Lachish III (Zimhoni 2004: Fig. 26.10: 3); (2) Registration number 11005/1 L4084, Lachish II (Zimhoni 2004: Fig. 26.44: 1).

Table 3: Provenance of Sub-type 1b

<table>
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<th>No. Jars</th>
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<td></td>
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<tr>
<td>7</td>
<td>Beth Shemesh</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Lachish</td>
<td>III</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Tel `Ira</td>
<td>VII</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Tel Malhata</td>
<td>III</td>
<td>The jar has only two handles</td>
</tr>
<tr>
<td>1</td>
<td>City of David</td>
<td>10</td>
<td>Only its upper body clusters into this group as its lower body is much longer than the rest of the jars</td>
</tr>
</tbody>
</table>
Figure 8  Representative examples, Sub-type 2a: (1) Registration number 1268/1L261 'Ira VII (Freud 1999: Fig. 6.59: 3); (2) Registration number 14135/1 L1004 Beer-sheba II (Unpublished).

<table>
<thead>
<tr>
<th>No. Jars</th>
<th>Site</th>
<th>Stratum/level</th>
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<tbody>
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<td>3</td>
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<tr>
<td>2</td>
<td>Tel 'Ira</td>
<td>VII</td>
</tr>
<tr>
<td>1</td>
<td>Arad</td>
<td>VI</td>
</tr>
<tr>
<td>1</td>
<td>Beer-sheba</td>
<td>II</td>
</tr>
<tr>
<td>1</td>
<td>Gezer</td>
<td>VIA</td>
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</tbody>
</table>
Figure 9  Representative examples, Sub-type 2b (1) Registration number 4869/1 L101, City of David (Unpublished); (2) Registration number G4830/1 L. unknown, City of David (Unpublished).

<table>
<thead>
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<th>No.</th>
<th>Jars</th>
<th>Site</th>
<th>Stratum/level</th>
<th>Comment</th>
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<tr>
<td>6</td>
<td>City of David</td>
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<td>Lachish</td>
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<tr>
<td>3</td>
<td>‘Ein Gedi</td>
<td>V</td>
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<tr>
<td>2</td>
<td>Tel ‘Ira</td>
<td>VI</td>
<td></td>
<td>One handle with a rosette stamp impression</td>
</tr>
<tr>
<td>1</td>
<td>Arad</td>
<td>VI</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Tel Malḥata</td>
<td>III</td>
<td></td>
<td>One handle with a rosette stamp impression</td>
</tr>
</tbody>
</table>
Figure 10  Representative examples, Sub-type 3a: (1) Registration number 8561/2 L.3582, Lachish III (Zimhoni 2004: Fig. 26.41: 5); (2) Registration number 30533/1 L4066, Lachish III (Zimhoni 2004: Fig. 26.19: 2).

TABLE 6: Provenance of Sub-type 3a

<table>
<thead>
<tr>
<th>No. Jars</th>
<th>Site</th>
<th>Stratum/level</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Lachish</td>
<td>III</td>
</tr>
<tr>
<td>2</td>
<td>Tel es-Ṣâfî</td>
<td>A3</td>
</tr>
<tr>
<td>1</td>
<td>Tel Š’ra</td>
<td>VII</td>
</tr>
<tr>
<td>1</td>
<td>Arad</td>
<td>?</td>
</tr>
</tbody>
</table>
FIGURE 11  Representative examples, Sub-type 3b: (1) Registration number 620147/3 L6201, Tell es-Safi/Gath (Unpublished); (2) Registration number 230216 L23025 Tell es-Safi/Gath A3 (Shai and Maeir 2003: Fig. 3: 6).

TABLE 7: Provenance of Sub-type 3b

<table>
<thead>
<tr>
<th>No. Jars</th>
<th>Site</th>
<th>Stratum/level</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Tell es-Ṣāfi</td>
<td>A3</td>
</tr>
<tr>
<td>4</td>
<td>Lachish</td>
<td>III</td>
</tr>
<tr>
<td>2</td>
<td>Gezer</td>
<td>VIA</td>
</tr>
<tr>
<td>1</td>
<td>Tel Batash</td>
<td>III</td>
</tr>
</tbody>
</table>
Figure 12  Representative examples, Sub-type 3c: (1) 4325/1 L1584, ‘Ira VI (Freud 1999: Fig. 6.101: 5); (2) Registration number 7103 L737, Tel Batash III (Mazar and Panitz-Cohn 2001: Fig. 16: 4).

Figure 13  Representative examples, Branch 4: (1) Registration number 4435/1 L175, ‘Ira VII (Freud 1999: Fig. 6.75: 3); (2) Registration number 30724/1 L4086, Lachish II (Zimhoni 2004: Fig. 26.45: 3).
Discussion

Typology

The computer-generated typology of the OSJ reveals the existence of six sub-types (1a, 1b, 2a, 2b, 3a, 3b). It is apparent that the difference between the *lmlk* and the *lmlk*-like jars is irrelevant, as has already been shown (Mazar and Panitz Cohen 2001: 94; Aznar 2005: 167–168; Gitin 2006: 508–509).

Study of pottery typology is usually based on visible features of individual vessels. While this information is valid and important, the computerized method has enabled us to quantify the uniformity of each group, which means the degree of similarity of a jar’s morphological features, or the mean distance between constituents of the same group. In this study, calculating the uniformity of shape and the capacity parameters (of jars clustered in the same sub-type) forms a critical component of the jar’s typology, which we label here as ‘standardization’.

It is clear that the sub-types of Branch 1 (1a and 1b) show the highest standardization level (Fig. 4). Sub-type 2b also shows a high level of uniformity, as demonstrated by the average of its morphological analysis (Fig. 4) together with the short range of its capacity values (Fig. 5). The uniformity values together with the capacity range of Sub-types 2a, 3a and 3b indicate a lower standardization level. Accordingly, it seems that Sub-types 1a, 1b and 2b demonstrate a high level of standardization and thus may be labelled as standardized jars. Sub-types 2a, 3a and 3b should be considered as non-standardized jars. The differentiation of standardized and non-standardized jars has significant historical and archaeological implications, as will be shown below. It is hardly surprising, therefore, that all the jars bearing stamped handles and thus representing the administrative-economic system of Judah, were clustered in the standardized sub-types (all jars carrying *lmlk* stamped handles were clustered in Sub-type 1b, while three out of four jars with rosette stamp handles were clustered in Sub-type 2b. The fourth one is a unique case in which the rosette stamp appears on a jar of unfamiliar shape).

Chronological distribution

The chronological distribution of the different sub-types is presented in Figs. 14 and 15, according to four chronological horizons:

• Horizon 1: The destruction of Stratum A3 at Tel eṣ-Ṣāfi, dated to the late 9th century BCE (Maeir 2004; 2008).
• Horizon 2: The destruction of Level VIA at Gezer and the destruction of Level 3 at Beth Shemesh, dated to the second third of the 8th century BCE (for dating the destruction

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4 When comparing, for instance, the uniformity values of Sub-type 2b against those of Sub-type 3b, it seems that the shape of the latter is more uniform than that of the former. However, adding to these values the low range of Sub-type 2b capacity clearly indicates that the production of Sub-type 2b aimed towards a much more standardized type than that of Sub-type 3b. It is not surprising, therefore, that Sub-type 2b is distributed in the same chronological horizon as Sub-type 3b and some of its components have stamped handles (more in the discussion below).

- Horizon 3: The destruction of Level III at Lachish and its concurrent strata (Tel ʿIra VII; Beer-sheba II), dated to the late 8th century BCE.⁶
- Horizon 4: The destruction of Level II at Lachish and its concurrent strata (City of David 10, Tel ʿIra VI, Arad VI, Ein Gedi V), dated to the early 6th century BCE.

The earliest appearance of the OSJ is in Level A3 of Tel eṣ-Ṣāfi/Gath, dated to the late 9th century BCE. This level yielded eight complete jars: Two of them belong to standardized Sub-type 1a and six to the non-standardized Sub-types 3a and 3b.⁷ All of these sub-types were also found in chronological Horizons 2 and 3 (early and late 8th century). The non-standardized jars of Sub-type 2a appeared in the destruction level of Gezer VIA but were in continuous use until the early 6th century (as one of them was unearthed in Arad VI). It is apparent, therefore, that the non-standardized types (2a, 3a and 3b) appeared as early as the late 9th century and were in use throughout the 8th and 7th centuries BCE. More surprising is the appearance of standardized jars as early as the late 9th century (Sub-type 1a) and in much more significant numbers in the destruction levels of Beth Shemesh 3 and Gezer VIA (Sub-type 1b). These are very close in shape (though still somewhat different) to the sub-types that in the next chronological horizon are stamped with the lmlk stamp impression (Sub-type 1a). It seems, therefore, that the predecessors of the jars used in the royal administrative system in Judah in the late 8th century appeared earlier in that century.

Jars of Sub-type 2b, some of which had rosette stamped handles, are confined to chronological Horizon 4 of Lachish II and its concurrent strata. Since there are no destruction levels in Judah between the late 8th and the early 6th centuries, it is difficult to suggest when during the 7th century the ceramic assemblage represented by Lachish III (including the OSJ of Sub-types 1a, 1b) was replaced by that of Lachish II (see Lipschits, Sergi and Koch 2011: 23–28). Nevertheless, Sub-type 2b should definitely be considered part of the family of the OSJ, as it shares many morphological features with Sub-types 1a, 1b, 2a and 3a, especially in the upper part of the body of the jars.⁸ Hence, it is safe to argue that the predecessors of Sub-type 2b are jars of Sub-type 1a and 1b and possibly even 2a. Since Sub-type 2b shows a high level of standardization, just like Sub-types 1a and 1b, we can conclude that the standardized types were in continuous use until the early 6th century.

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⁵ Although these two destruction layers are considerably far apart from each other, we find it preferable to group them together into a chronological horizon prior to the 701 destruction.

⁶ The excavators of Tel ʿIra dated Stratum VII to the late 8th and the beginning of the 7th centuries BCE (Beit-Arieh 1999: 171–173; Freud 1999: 194–214). Yet, we accept Singer-Avitz (1999: 56) and Thareani-Sussely (2007: 71–72), who dated this stratum to the late 8th century and its destruction to 701 BCE.

⁷ The ninth jar clustered into Type 3c and thus is not included in the discussion.

⁸ Note one incomplete jar from the City David that clustered with jars of Sub-type 1b.
In summation, it is possible to reconstruct four chronological stages for the development and use of the OSJ:

The first stage, dated to the late 9th and the early 8th centuries BCE, is characterized mainly by the manufacturing of non-standardized sub-types (3a, 3b, 2a).

The second stage is dated to the early- to mid-8th century BCE. The jars became more standardized, as is attested by the parameters of Sub-type 1b.

The third stage is dated to the late 8th century BCE. The standardization process continued and the jars were adopted for use by the royal administrative system of Judah, as can be demonstrated by the appearance of stamp impressions on their handles.
The fourth stage is dated from the mid/late 7th century to the early 6th century BCE. The tradition of manufacturing standardized OSJ continued well into the early 6th century BCE but the stamping design was replaced.

The standardized jars existed side by side with the non-standardized ones, which were possibly used for needs other than those of the administrative system, though their numbers dropped: non-standardized jars appear in much larger numbers in the early chronological horizons (late 9th–early 8th centuries), while their numbers diminished in the later periods (late 8th and 7th centuries), when the standardized types constituted the majority of the jars.

Methodological note concerning the spatial distribution of the jars

About 70% of the complete jars derived from the lowlands, 20% from the Negev and only 10% from the mountain ridge and the Judean Desert. This stands out against the distribution of the stamped handles, which were found in large quantities in the mountainous region, especially at Jerusalem, Ramat Rahel and sites in Benjamin (see the recent corpus of stamped handles compiled by Lipschits, Sergi and Koch 2011: 30–35). This contrast evokes a methodological problem, since the complete jars were found particularly in destruction levels. The Judahite lowland regions (the Shephelah and the Beer-sheba–Arad Valleys) suffered two major destructions: the first in the late 8th century and the second in the early 6th century BCE. On the other hand, the hill country and Jerusalem in its centre suffered only the second of these destructions. This may explain the striking inconsistency concerning the jars found in Jerusalem; while Jerusalem yielded more than 285 early and late lmlk stamped handles, not even a single complete jar bearing those handles was ever discovered there. The number of lmlk stamped handles is evidence that the royal storage jars were in use in Jerusalem during the late 8th–early 7th centuries BCE. Their complete absence from the ceramic assemblage is due to the lack of a destruction level from that period. This methodological note also bears an important implication: complete vessels found in destruction levels represent only their last days of use and cannot attest to longer historical development.

Figures 16–18 show the geographical distribution of the different sub-types of the OSJ. As can be seen in Fig. 16, the early appearance of the jar is confined to the Shephelah. This pattern fits well with the results of provenance studies that placed the manufacture of all OSJ in that region (Mommsen, Yellin and Pearlmann 1984; Goren and Halperin 2004; Aznar 2005: 166–169). The non-standardized types were distributed mainly in the Shephelah (21 jars of Sub-types 2a, 3a, 3b) while they were found in the Beer-sheba–Arad Valleys in much smaller quantities, though this area features concurrent destruction levels (only six jars of the non-standardized sub-types). Moreover, the non-standardized jars appear in large numbers in Shephelah sites that were not in the territory of Judah (Tell es-Sāfi and Gezer).

Contrary to the limited distribution of the non-standardized types, Figs. 16 and 17 show that the standardization of the jars and their adoption into the royal administrative system expanded their distribution and brought them to all the different geographic regions of the Kingdom of Judah. At the same time the provenance study of these jars indicates that they were still manufactured mainly in the Shephelah, and that it was only at the end of
In the Iron Age that production of some jars began in the environs of Jerusalem (Yellin and Cahill 2003; 2004; Aznar 2005: 166–170).

The assemblage of the standardized jars found in the Beer-sheba–Arad Valleys is characterized by a small quantity of jars. Contrary to the situation of Jerusalem, where many stamped handles but not even a single jar was found, in the Beer-sheba region the small quantity of jars is consistent with a small number of stamped jar handles. This observation indicates that the Beer-sheba–Arad Valleys were only of marginal importance in the administration system associated with the lmlk and later with the rosette stamp impressions (see also Lipschits, Sergi and Koch 2011: 14–15, 19–23).

**Figure 16** Spatial distribution of jars in Horizons 1 and 2 (Tell es-Sāfi/Gath A3, Beth-Shemesh 3, Gezer VIA).
Conclusions

More than 100 OSJ from diverse regions and sites and from different archaeological strata and chronological horizons were examined in this study. Using computerized analysis, six sub-types of these jars were identified.

Our study shows that the terms introduced by Zimhoni—lmlk and lmlk-like jars—should be abandoned. The term pre-lmlk, suggested by Shai and Maeir (2003), should be avoided as well, since it does not reflect the process of the development of the jars. The main difference between the sub-types of the OSJ is their uniformity and level of standardization. Since the non-standardized jars were found in destruction levels dated to the late 9th and to the late 8th centuries BCE, side by side with the standardized jars, the chronological term ‘pre’ is not appropriate and can only obscure the real process described above. Gitin’s (2006: 508–509) neutral label—‘Oval Judahite Jars’—should
be rejected since the origin of the jars, and long periods of its development were not connected with Judah.

The OSJ were first produced as local Shephelah vessels. In the first stage, during the late 9th and early 8th centuries BCE, they were characterized mainly by non-standardized sub-types; in the second stage, down to the early mid-8th century BCE, they developed gradually, as the standardized jars became more common than the non-standardized jars. The process described here reflects an important change in the way pottery production was organized (Costin 1991; Hayden 1995). Changes in production mode, especially the move from household production to more specialized production workshops (Van der Leeuw 1984: 754) is usually connected with a process of social and economic integration. In the case of the OSJ the change in the manufacturing process, namely their gradual standardization in the early mid-8th century BCE reflects the consolidation of the Kingdom of Judah and its territorial expansion into the lowland region, which
took place throughout the 9th century BCE (Finkelstein 2003; Herzog and Singer-Avitz 2004; Finkelstein and Fantalkin 2006; Fantalkin 2008). The standardization of the jars indicates a more centralized production and consumption that should be associated with the consolidation of the Judahite political hegemony over the lowland region. The next phase in the history of the OSJ, during the late 8th century BCE, is the adoption of these jars into a royal administrative system: workshops producing these jars (or one main production centre?) became integrated into the royal administrative system connected with the stamped jar handles, which dictated their main function until the destruction of Judah in the early 6th century BCE. During this stage, the jars were used for the royal economy, which expanded their distribution throughout the kingdom, though they were still produced at the same centres located somewhere in the lowlands, probably in the Valley of Elah (Socoh?).

The continuous manufacturing of the non-standardized jars until the early 6th century BCE indicates that these types were in use side by side with the standardized types, probably representing some local functions unrelated to organized trade or to the royal administrative system.

Finally, it should be noted that the uniformity of the jars’ shapes is an indication of the specialization of the production process but not necessarily of their use in a centralized administrative system (as is demonstrated by Type 3b, which has a somewhat unified shape but the highest range of capacity). Only when uniformity of the shape also affects volume do we observe a standardization process that brought the jars into a centralized administrative-economic system; in our case this is represented by Sub-types 1a, 1b and 2b, standardized in the early to mid-8th century with the consolidation of Judah. Yet, even the standardized jars have quite a range of capacity (10–12 litres), indicating that the liquid in the jars was not measured by precise calculations but was probably determined by the jar’s shape.

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