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The Impact of Needle Evolution on Embroidery
Focus on the Spring and Autumn and the Warring States Periods

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Abstract

Different needs and techniques have led to the creation of different tools that act as a bridge between the objects to be processed and the objects to be used, and these tools have influenced the emergence and development of traditional craft civilizations. It is important to note that these tools were created based on specific times and conditions. Taking embroidery needles as a starting point, this paper examines the influence of needle evolution on the progress of needlework during the Spring and Autumn (770-476 BC) and Warring States periods (475-221 BC), analyzing excavated objects and documentary records and emphasizing the interplay between tools and techniques. The evolution of needle materials, structures and sizes reflects the law of change in response to time, linked not only to the development of productive forces but also to complex and profound social changes.

Keywords: Embroidery, lock stitch, needle, productive forces, the Spring and Autumn and Warring States periods

1. Introduction

"To perform well, it is essential to have the appropriate tools." Tools are not only processing instruments that conform to the characteristics of materials and objectively present the innate properties of materials but also function as extensions of the hands that consciously reveal the skill level of craftsmen. As a bridge connecting the processing subject (material) and the user (person), tools influence the birth and formation of traditional craft civilization.

Embroidery, a decorative technique in which silk thread or other fibers or yarns are pierced through a base fabric in a specific pattern and color with a needle, creates patterns through stitches. As a means of communication between man and object, the needle is an essential tool in embroidery. It adapts to the specifications and characteristics of threads and fabrics, embodying the craftsmanship wisdom revealed in needlework. Needlework is the technical means by which embroidered products take shape, with both the needlework (technique) and the needle (tool) as key elements in the creation of embroidered products. The material, structure, size, and performance of the needle act as important guarantees for the generation, development, and improvement of embroidery techniques. Specific eras, conditions, needs, and technological advancements have given rise to different tools, and the evolution of embroidery needles follows its own historical trajectory. The emergence, development, and maturity of needlework mark a continuous process as it traverses the stages such as formation and development (from the Neolithic Age to the end of the Eastern Han Dynasty), improvement and refinement (from the Wei and Jin Dynasties to the Yuan Dynasty), and integration and innovation (from the Ming Dynasty to modern times). During the formation and development of needlework, a significant transformation from primitive simplicity to intricate diversity occurred, especially during the Spring and Autumn and the Warring States periods.

The period from 770 BC to 221 BC is a transitional phase from the late Bronze Age and the early Iron Age, characterized by innovation and development in labor tools, improved productivity, changes in social systems, and a flourishing of thought and culture. This article employs the evolution of embroidery needles as a clue, combines the development laws of needlework, and explores the impact of tool evolution on the development of needlework through the excavation of artifacts and historical records. The aim is to interpret the relationship among tools, productivity and social structure from a textile perspective, and to outline the interaction between tools and skills.

2. The Concept of Embroidery Needles

According to the Modern Chinese Dictionary, "embroidery needles" in this article are defined as "tools for sewing clothes, such as embroidery needles, sewing needles, and knitting needles." Needles for embroidery share a similar structure with sewing needles but differ in size and the sharpness of the needle tip. Sewing needles are larger in size with a blunter tip compared to embroidery needles. In the early days, tools were used for multiple purposes, and there was no strict classification of needles. Needles used for sewing and embroidery are mainly distinguished by their thickness in the modern embroidery market. Combined with the classification of embroidery needles in the *Xue Yi Xiu Pu* (雪宧绣谱) and the temporal context of this study, embroidery needles, as one of the textile tools, include embroidery needles, beading needles, cross-stitch needles, knitting needles, and sewing needles. This expanded scope takes into account the practicality of labor tools and the symbolism of folk culture.

Embroidery needles are one of the important tools in the needlework activities of ancient women. They pierce the fabric, thread through the needle, and collaborate with needlework to create patterns. The material, structure, size, and performance of needles serve as important guarantees for the generation, development, and improvement of needlework. Materials such as stone, bone, bronze, steel, and even gold and silver have been used as raw materials for embroidery needles (Wang, 2008). These needles, characterized by their slender and pointed objects, consist of three components: the needle tip, body, and handle. (Figure 1) The length, diameter and eye size of the needle body are key factors that determine its overall size.

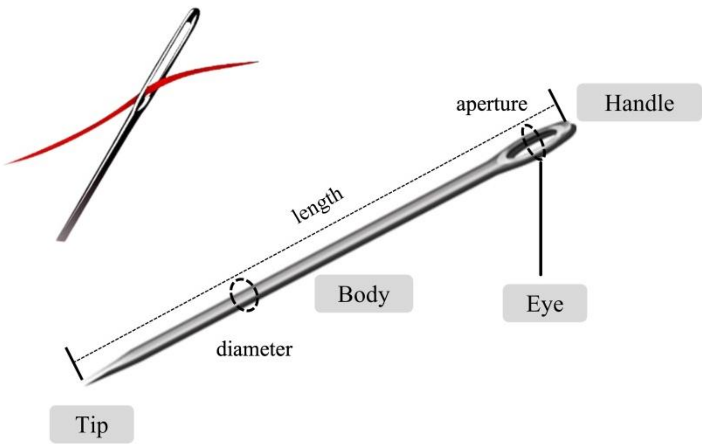

Figure 1. The Structure and Dimensions of Embroidery Needles

The performance of needles is influenced by the material, structure, and size. Sharp needle tips, straight needle bodies, and smooth surfaces enable flexible movement and reduce friction during piercing. A smaller diameter and aperture result in finer needle tips, making it easier to conceal the needle and ensure overall smoothness in the embroidered piece. The flat needle handle aids in the passage of the thread through the fabric. Embroidery needles are designed to be compatible with the fabric, thread, and embroidery techniques. The fineness of the needle correlates with fabric gaps (fabric density), while the length corresponds to the thickness of the fabric. The diameter or aperture should match the thread being used. Moreover, embroidery needles align with needlework parameters, where the thickness of the needle matches the length of the needle stitch and the density of stitches. Additionally, the various sizes of embroidery needles enrich the range of unit patterns, with smaller needles well-suited for intricate designs, highlighting the details of the patterns during embroidery.

3. Embroidery Needles during the Spring and Autumn and the Warring States Periods

Specific eras, conditions, needs, and technological advancements led to the creation of different tools. From 770 BC to 221 BC, many bone needles have been unearthed throughout the country (Note 1), such as the Nanshan Gen Site in Ningcheng County, Liaoning Province (1100-400 BC), the Zhagunluke Site (900-300 BC), and the Kashahu Stone Coffin Tomb in Luhuo, Sichuan Province (900-200 BC). There have also been occasional discoveries of metal needles. Historical records abound with evidence that metal needles were widely used as tools for women's needlework throughout the country and became the basis for the establishment of large-scale, specialized needle-making workshops.

3.1 Widespread Use of Stable-Structured and Small-Sized Bone Needles

Bone needles made their debut in the late Neolithic period, but their quantity was limited until the Bronze Age, during which they were unearthed in large numbers. Bone needles were capable of various functions such as piercing, counting, threading, sewing, and embroidery (Cai, 2023).

The abundance of bone needles unearthed during the Spring and Autumn Period and the Warring States Period indicates their widespread use as tools. The structure and size of bone needles underwent changes during this period. While retaining the basic structure (needle tip, needle body, and needle handle), there was a trend toward straighter needle bodies with mostly circular cross-sections, and single-eyed needles became predominant. d'Errico et al.conducted a statistical analysis of eyed bone needles (EBN) from the Chinese Stone Age and found two types of cross-sections: circular, represented by the Zhoukoudian and Xiaogushan cave sites, and flattened, represented by the Shuidonggou site (d'Errico et al., 2018). Circular cross-sections were found to be more suitable for sewing and decorative work, and the bone needles unearthed during the Spring and Autumn Period and the Warring States Period mostly had circular cross-sections. Bone needles from the Stone Age exhibited three forms of needle eyes: no hole, single hole, and double hole. No-hole bone needles served separate functions for piercing and threading with lower efficiency. Double-hole bone needles were formed when the original needle hole broke during use, followed by subsequent processing to create new holes. The selection of high-quality bone materials, advances in grinding techniques, and the establishment of specialized bone-making workshops contributed to increased needle strength, effectively reducing the breakage of needle eyes during use. Consequently, single-eyed bone needles are the primary and preferred type.

The size variation of bone needles is quite significant. During this period, the size of bone needles exhibited a trend towards smaller dimensions, characterized by shorter lengths, narrower diameters, and smaller apertures. In the early and middle stages of the Neolithic Age, bone needles displayed a broader size range, with lengths ranging from 29 to 212 mm, diameters from 0.8 to 6.4 mm, and apertures from 0.5 to 1.4 mm (Tao, Wang, Liu, & Zhu, 2018). This indicates the need to process different thicknesses and textures of textile materials. Bone needles with lengths greater than 90 mm and larger diameters may not have been suitable for sewing and embroidery but could have been employed for counting to control the warp and weft (Tao et al., 2018). In the late Neolithic period, the length, diameter, and aperture of bone needles gradually became smaller (Note 2). In the Bronze Age, the width of bone needles fell below 2 mm, with nearly half of them reaching around 1mm. At the Nanshangen Site, seven bone needles were discovered with an average length of 75 mm and a needle eye diameter of 0.5 mm. At the Zhagunluke M41 site, a bone needle with a length of 59 mm and a needle eye diameter of 0.9 mm was unearthed. The ever-increasing proportion of shorter and thinner needles indicates a shift in the objects being processed towards finer and thinner base materials, along with embroidery threads reaching millimeter-level fineness. It also reflects the ability of bone needles to perform more delicate and flexible work, indicative of the development of sewing and needlework and advancements in textile technology.

3.2 Appearance and Gradual Replacement of High-Performance Metal Needles after the Warring States Period

Metal needles were gradually used for sewing and embroidery during the Spring and Autumn and the Warring States Periods, as inferred and substantiated from historical records, character analysis, and unearthed artifacts.

Metal needles, as tools for women's needlework, are widely mentioned in historical records. The book *Guanzi・Light and Heavy B* (管子 轻重乙) states, "A woman must have a knife, an awl, a needle, and a file before she can engage in women's work." In the *Guanzi・ Hai Wang* (管子 海王) stated, "Today, the number of iron officials is as follows: a woman must have a needle and a knife." With the development of smelting technology during the late Spring and Autumn Period, iron needles became integral to women's needlework. In 589BC of *the Book of Rites* (左传), craftsmen such as tailors (holding needles) and weavers were presented to the State of Chu by the State of Lu. Additionally, further support for the evolution of needle materials is found in character analysis. The *Shuowen Jiezi* (An Explication of Written Characters) records two types of needles, "箴" (zhēn) and "鍼" (zhēn). The bamboo or wooden awls were primitive sewing tools used for stitching and mending, while the metal awls represented an advanced sewing tool employed for sewing and garment making. The *Shuowen Jiezi*, written in the first year of Jianguang (121 AD), indicates that metal needles were already widely used in sewing and embroidery prior to the Eastern Han Dynasty.

Copper smelting first emerged during the late Neolithic period, but the technology remained relatively rudimentary. However, during the Shang Dynasty, alloy technology was developed to enhance the strength and hardness of copper by adding tin and lead elements to meet specific needs. Between the late Warring States Period and the early Eastern Han Dynasty, 14 copper needles were discovered at the Li Family Mountain site. These needles, generally about 6cm long with pointed ends and no needle eyes, exhibit a different structure compared to the previous embroidery needles. Although archaeological reports did not definitively determine the use of these copper needles, the presence of needle cases, silk threads, and other textile tools found in the same tomb suggests that copper needles were indeed used for sewing or embroidery.

During the Mid-Spring and Autumn Period, China entered the Iron Age, and by the Warring States Period, iron had become widely used in various aspects of social production and daily life (Xu, 1990). The excavation of many iron artifacts at the Houma pottery kiln site in Shanxi Province over 200 years ago reflects the transition from the Bronze Age to the Iron Age in this region (Houma work station of Shanxi Provincial Cultural and Management Association, 1959). The unearthed iron needles at this site were rough, with bent needle bodies and thick diameters (Figure 2). During the mid-Warring States, the Bao Mountain M2 site in Jingmen yielded the earliest known steel needle in China (Hubei Jingsha Railway Archaeological Team, 1991). This needle featured a flat needle nose, oval-shaped eye, round cross-section, and a damaged needle tip (Figure 3). With a diameter of 0.8mm, an eye size of 0.6mm, and a remaining length of 8.18cm, its dimensions bear resemblance to modern embroidery needles. Eight composite tools made of steel, iron, and copper unearthed from the same tomb reflect the progress in metal smelting technology in the State of Chu at that time in terms of alloy composition and casting techniques.

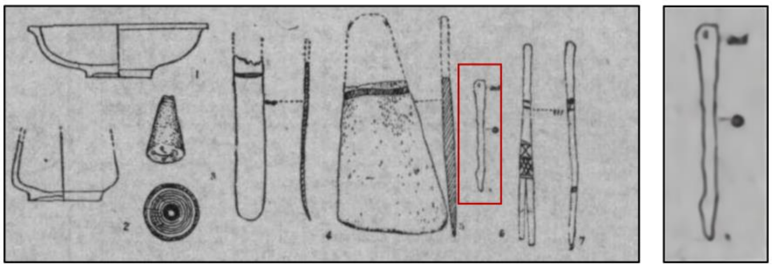

Figure 2. Iron needles unearthed from the Houma Pottery Kiln Site in Shanxi Province

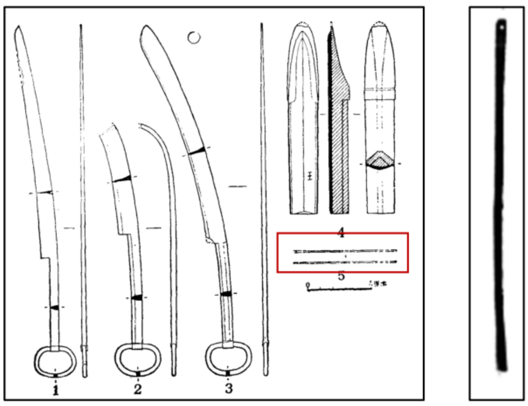

Figure 3. Steel needles unearthed from Tomb No. 2 in Baoshan, Jingmen, Hubei Province

During the Spring and Autumn Period and the Warring States Period, metal needles gradually began to be used as embroidery tools. Copper needles may have been among the earliest metal needles used, but cost-effectiveness (d'Errico et al., 2018) and limitations in strength and durability (Zou, 2015) resulted in their rarity in archaeological remains and their infrequent use during that period. Mature bone needles were mainly used during this time (Note 3). The development of solid-state carburizing and quenching techniques in iron smelting improved the strength and durability of steel needles, allowing the needle bodies to be finely worked without breaking, the needle tips to be sharpened, and the needle eyes to be made smaller, making it easier to depict and express fine patterns. Steel needles gradually replaced bone needles as the preferred choice for embroidery due to their convenience in storage and transportation, laying the foundation for the basic paradigm of embroidery needles in subsequent periods.

4. The Improvement and Progress of Needlework during the Spring and Autumn and the Warring States Periods

From the late Neolithic to the end of the Eastern Han Dynasty witnessed the formation and development of embroidery techniques. Three major basic stitching techniques (lock stitch, flat stitch, and seeded stitch) were initially established, with lock stitch occupying the main position. Lock stitch served as the foundation for various embroidery techniques such as open-work, closed-work, single-line, multi-line, positive and negative variations, and edge stitching. Flat stitch held a secondary position and gave rise to composite techniques such as satin stitch, couching stitch, counting stitch, as well as decorative techniques like clip and paste embroidery. Lock stitch prevailed in the embroidery artifacts unearthed from the Spring and Autumn and Warring States periods. The technique underwent enrichment through variations in the form of openings, stitch length, and stitch density.

4.1 Lock Stitch as the Main Needlework

During the Spring and Autumn and Warring States periods, the main embroidery technique used was the lock stitch, in which a pattern of interconnected loops is created on fabric by means of the loop stitch technique. As long as the stitch length and curvature were consistent, there was no need for meticulous shading effects. The resulting patterns were sturdy and durable, with interlocking chains to prevent slipping, and the motifs had a three-dimensional quality and visual effect.

According to the closure form of the loops, lock stitching exhibits two basic forms: opening form and closed form. Considering the coordination between the lock stitching loops and the needle, two derived techniques have been developed: double-loop lock stitching (two loops pressed with one stitch to create a tight edge) and braid stitches (the previous loop pierced with the needle to press through the second loop, and pulling up the thread, with the process repeated) (Figure 4). The achievement of different needlework is possible through adjustments to the embroidery process parameters. Changing the arrangement order of the lock stitching loops (front and back loop directions) can result in parallel-style and return-style. Different numbers of filling loops have led to the development of single-row, double-row, and multi-row lock stitching.

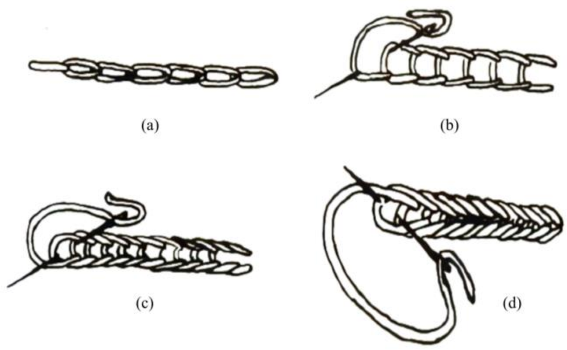

Figure 4. Classification of Lock Stitch: a. Closed Lock Stitch; b. Open Lock Stitch; c. Double-loop Lock Stitch; d. Braid Lock Stitch

4.2 Fine and Diversified Development of Lock Stitch

Embroidery traces discovered in Western Zhou tombs in Baoji, Shaanxi Province, used lock stitching as the basic stitching method. Single lines were used to outline contours, with occasional incorporation of double lines to enhance decorative effects. The embroidered huangwei (a type of embroidery relic) unearthed in Hengshui, Jiang County, Shanxi Province, is recognized as the best-preserved and largest archaeological relic of the Western Zhou period in China. It was embroidered with single-row lock stitching to depict the outlines of phoenixes and birds, with a small amount of multi-row lock stitching for filling to create three groups of differently-sized bird patterns. Lock stitching in the Western Zhou period mainly used basic stitching methods, with single-row or double-row stitching. Multi-row filling was relatively infrequent during this era. The emphasis of the patterns lay in the overall construction of the edge contours, with localized embroidery. Overall, fewer stitches were used, with longer needle distances and smaller needle marks.

During the Spring and Autumn and Warring States periods, lock stitch in embroidery underwent development and refinement. Excavated from the tomb of Huang Junmeng and his wife in Henan, the stolen qu pattern embroidery was executed on a plain-woven silk fabric using three to four colored threads. The unit pattern measured 2 cm in height and 1.5 cm in width, with a spacing of 6-7 mm between rows and 7 mm between units. In the tomb of Li Zhou’ao in Shuikou Township, Jing’an County, Jiangxi, and the Eastern Zhou M1 site in Langjiazhuang, Linzi, numerous embroidery fragments were unearthed. The embroidered ribbons featured whirlpool patterns and variant S-shaped patterns created with non-twisted silk threads on brown silk fabric using closed-loop lock stitching. Depending on the pattern requirements, single rows, double rows, or multiple rows were combined to enhance the expressiveness.

In the Warring States period, lock stitching underwent even more diverse changes compared to the Spring and

Autumn period. Many exquisite embroidery pieces were excavated from sites such as Wuli Pai M406 in Changsha, the tomb of Marquis Yi of Zeng in Hubei, Lishi Martyrs Park M3 in Changsha, Wangshan in Jiangling, Baoshan M2 in Jingmen, and Mashan M1 in Jiangling. The main part of the patterns on the Baoshan M2 embroidery was fully covered by multiple rows of lock stitching, with single rows, double rows, or multiple rows forming lines according to the composition needs. The stitching density was high, with lock stitch loops measuring 1.5-4 mm in length and 1-3 mm in width. 18 embroidered pieces were discovered at Mashan in Jiangling, predominantly utilizing silk as the base fabric and double-stranded synthetic threads measuring 0.15-0.25 mm. Multiple rows of lock stitching were used to cover large areas for filling, while single or double rows were used to express specific parts of the pattern. Some patterns even incorporated up to 9 rows at the turning points to convey the soft and curved texture of the embroidery (Gao, 1996). The stitches were shorter in these cases, with lock stitch loops between 0.7-4 mm in length and 0.4-1.2 mm in width. Pattern sizes varied, with the largest one being a silk fabric with a dragon and phoenix pattern measuring 181 cm in length.

Table 1. Excavated Lock Stitches from the Western Zhou to the Warring States Period

Periods	Source	Picture
Western Zhou Dynasty	Embroidered Traces from Western Zhou Tombs in Baoji, Shaanxi Province	
	Embroidered Huangwei Relic from Hengshui, Jiang County, Shanxi Province	
Spring and Autumn Period	Purple Embroidered Silk Fabric from the Tomb of Huang Jun and his Wife, Henan Province	
	Embroidered Ribbon from Langjiazhuang, Linzi, Shangdong Province	
Early Warring States Period	Fragments of Dragon and Phoenix Embroidery from the Tomb of Marquis Yi of Zeng, Hubei Province	
	Embroidery 1 on the Eastern End Panel of an Outer Coffin in Lishi Martyrs Park, Changsha, Hunan Province	
Late Warring States Period	Embroidered Large Quilt with Phoenix and Bird Patterns from Baoshan M2, Hubei Province	
	Embroidered Quilt with Dragon and Phoenix Patterns from Mashan M1, Hubei Province	

The development of lock stitching during this period exhibited characteristics of refinement and diversification. As stitch length gradually decreased, stitch density increased. Single-row lock stitching was used to outline the pattern's contours, and multiple rows were primarily used for covering and filling—a departure from the arrangement rules in the Western Zhou period, where single rows were predominantly used with multiple rows as secondary. Lock stitching gave rise to various forms of variation, such as open, closed, and double-loop stitching. Changes in the curvature and arrangement direction of the loops were introduced to suit the diverse styles of patterns. Furthermore, the range of embroidery pattern sizes expanded, during this period allowing for detailed portrayals.

5. The Evolution of Embroidery Needles and the Improvement of Needlework

The advancement of production tools promotes social productivity, and the evolution of embroidery needles has also contributed to the improvement of needlework techniques. After developments in the Stone Age, the structure and size of bone needles gradually stabilized. The emergence of specialized workshops further boosted the efficiency of needle production. Bone needles, combined with appropriate craft parameters, were able to execute the basic forms of lock stitching, laying the foundation for the development of embroidery techniques. The introduction and widespread use of metal needles, as well as the small size of bone needles, facilitated the refinement and diversification of needlework. Different artistic styles of embroidery appeared through the orderly combination of needles, threads, fabrics and techniques.

5.1 Stabilization of Bone Needle Structure and Size and the Maturation of Production Techniques Lay the Foundation for the Development of Needlework

Between 770 BC and 221 BC, the structure and size of bone needles exhibited increased stability compared to the Neolithic period. Production techniques for bone needles included bone selection, cutting, scraping, polishing, and drilling. Purposeful selection of bone materials and the use of advanced scraping and polishing techniques ensured that needle shafts were processed to be straight and smooth. Advancements in drilling techniques and stronger bone materials have reduced the likelihood of needle breakage during use. The proportion of bone needles with a circular cross-section increased during this period, indicating that they were primarily used for sewing and embroidering, and marking a gradual replacement of functions such as counting and warp guiding. The needle's straight and smooth body, sharp tip, flat handle and single eye structure reduced damage to the tool and the occurrence of needle breakage. This lessened damage to the embroidery thread and fabric and provided the basis for creating, developing and improving embroidery techniques. Different sizes of bone needles could fulfill different functions, such as large bone needles (length greater than 90 mm) were less common, small-sized bone needles became the main type. Bone needles with a diameter as small as 0.5 mm provided a material basis for the refinement of sewing techniques and the advancement of embroidery skills.

During the Western Zhou and Spring and Autumn periods, bone needles were primarily used for embroidery. Bone needles could achieve the two basic forms of lock stitching and enhance decorative effects through single or double-row arrangements. However, in these arrangement rules, single-row stitching for outlines was predominant, and parallel arrangements with multiple rows were less common. The stitch length was longer, and the embroidery density remained relatively low, likely constrained by bone needle size and bone material strength (Wang, Bae, & Xu, 2020). During the Spring and Autumn and Warring States periods, the use of bronze tools facilitated the production of bone objects on a larger scale in specialized workshops (He & Li, 2022). This marked a significant improvement in the efficiency of bone needle production to meet the high demand for social production.

5.2 Innovation in Materials and Small Size Promote the Refinement and Diversification of Needlework

During the Western Zhou and Spring and Autumn periods, lock stitch was primarily arranged in a single-row filling pattern, occasionally using double-row or multi-row for localized decoration. The stitches tended to be longer, with relatively rough embroidery. However, lock stitch underwent refinement and development during the mid to late Warring States period. This progress was characterized by variations in stitch length, stitch density and combinations of single, double and multi-row techniques, closely linked to the introduction and application of metal needles. In the late Warring States period, metal needles emerged as the mainstream needles due to their higher hardness, greater toughness, and smaller dimensions. The shorter needle shaft, smaller diameter, and finer aperture allowed for flexible adjustments in stitch length, density, and direction. Adding or reducing the number of loops (single-row or multi-row) enriched the variety of needlework.

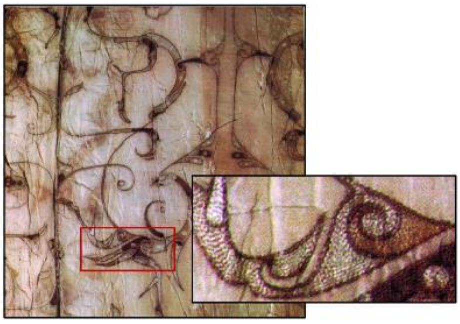

Figure 5. Embroidery of Phoenix and Dragon Pattern Unearthed from M1 in Mashan (N7)

The unearthed fragments of dragon and phoenix pattern embroidery from the early Warring States period, found in the Tomb of Marquis Yi of Zeng, mainly featured multi-row lock stitch. These fragments portrayed a dragon pattern with a varying needle direction with a relatively high total number of embroidery stitches. In the middle Warring States period, the stone-character pattern embroidery discovered in the Wangshan Tomb of Chu was executed on silk fabric with a warp density of 78 threads per centimeter and a weft density of 30 threads per centimeter. The wave-like patterns were embroidered with a combination of twisted thread (usually thicker) and tacked thread (usually finer), which requires the use of different-sized embroidery needles. The embroidered artifacts unearthed from the Mashan and Baoshan sites in the late Warring States period reached new heights of exquisiteness and magnificence. The lock-stitch embroidery of the N7 pair of phoenix and dragon patterns (Figure 5) featured shorter coil lengths, ranging from 1.1 mm to 2 mm in length and 0.6 mm to 0.8 mm in width. Multi-row lock stitch was applied for overall pattern formation, while single-row was reserved for localized decoration. The lock stitch lines were smooth, and the embroidery work demonstrated a high level of delicacy and craftsmanship. Needlework improved with the use of stable bone needles and high-quality steel needles, building upon the foundation of lock-stitch needlework.

5.3 The Combination of Needles, Threads, and Needlework Enriches the Artistic Style of Embroidery Works

Embroidery needles serve as a bridge between needlework and materials, and their size should match the selection of threads and fabrics. Silk embroidery was used to show the luxurious and noble qualities of silk during the Spring and Autumn and Warring States periods. With advancements in silkworm cultivation and silk reeling techniques, the cross-sectional area of single silk cocoons increased. Different thicknesses of raw silk were obtained through the proportioning of silk cocoons, as recorded in *the Book of Songs ·Zhaonan ·Gaoyang* (诗经 ·召南 羔羊). In Mashan M1, the fineness of embroidery threads ranged from 0.1 mm to 0.5 mm, while in Baoshan M2, the embroidery thread was 0.2 mm. It was observed that there was a trend towards finer embroidery threads, which required the use of smaller needles for embroidery.

Silk fabrics expanded from plain weave silk, gauze and leno to more complex variations such as silk fabrics using plain derivative weaves, taffeta, twill brocade and compound weave satin as counting techniques and the variety of fabric structures developed. The fabric density evolved from coarse and sparse weaves to high-density compositions. In the Spring and Autumn period, plain silk exhibited a warp density of 48 threads per centimeter and a weft density of 43 threads per centimeter. In the Warring States period, the deep brown plain silk found in the Yihouyi Tomb of Zenghou boasted a warp density of 96 threads per centimeter, while the phoenix and bird embroidered quilt in Baoshan M2 reached a warp density of 104 threads per centimeter. The increased warp and weft density of the embroidery fabric contributed to a reduction in porosity. In view of these developments, it was necessary to select appropriately sized needles to match the fabric. Large needles for embroidery at this time would create larger holes, which could cause damage to the fabric as well as shrinkage and shift of the embroidery pattern.

Therefore, there is a regularity to needle, thread and fabric combinations. For fine and light fabrics it is advisable to use finer threads and smaller needles. This combination extends the range of sizes for embroidered unit patterns, enhances the expression of details and provides technical support for the delicate and romantic artistic style of the embroidered works.

6. Conclusion

The evolution of materials, structures, and sizes for embroidery needles has driven the development of embroidery techniques. The stable structure and size of bone needles, along with well-established manufacturing processes, laid the foundation for this development. Needlework was refined and diversified through innovations in materials and smaller needle sizes. The progress made in weaving and the advances made in tools have complemented each other. Benefiting from advances in silkworm breeding, silk reeling techniques and counting skills, the fineness of threads and the increased density of fabrics require matching embroidery needles. The artistic style of embroidery is enriched by the combination of needles, threads and fabrics.

The period between 770 BC and 221 BC marked the transition from slave to feudal society, facilitated by the development of productive forces in which iron tools played a significant role. Needles, despite their small size, are versatile tools for various crafts. The evolution of embroidery needle materials, structures and sizes reflects the law of adaptation and evolution with the times, signifying the progress of productive forces and also reflecting complex and profound social changes.

References

Cai, K. (2023). *Research on the development of Pre-Qin tools.* Nanjing: Nanjing University of the Arts. https://doi.org/ 10.27250/d.cnki.gnjyc.2022.000017

d'Errico, F., Doyon, L., Zhang S., et al. (2018). The origin and evolution of sewing technologies in Eurasia and North America. *Journal of Human Evolution, 125,* 71-86. https://doi.org/10.1016/j.jhevol.2018.10.004

Gao, H. Y. (1996). *Jiangling Wangshan Sha Tomb Chu*. Beijing: Cultural Relics Publishing House.

He, Y. L., & Li, Z. P. (2022). Exploration and achievements of excavation methods in the bone workshop of Huanbei Shangcheng. *Cultural Relics of Central China, 2,* 102-107. Retrieved from http://www.cnki.net

Houma work station of Shanxi Provincial Cultural and Management Association. (1959). Houma Eastern Zhou Dynasty pottery kiln site excavation summary. *Cultural Relics, 6,* 45-46+44. Retrieved from http://www.cnki.net

Hubei Jingsha Railway Archaeological Team. (1991). *Baoshan Chu Tomb*. Beijing: Cultural Relics Publishing House.

Tao, Y., Wang Q. C., Liu Y. N., et al. (2022). The origin, evolution, and process of Bone Needles and "Thread" -like soft materials. *Silk, 59*(11), 126-132. https://doi.org/10.3969/j.issn.1001-7003.2022.11.016

Wang, B. (2008). Needle: A typical case of technological impact on society. *Proceedings of the 2008 National Doctoral Forum of Shanxi University (Philosophy of Science and Technology)*. Office of the Academic Degrees Committee of the State Council, Department of Degree Management and Graduate Education of the Ministry of Education.

Wang, W., Bae, C., & Xu, X. (2020). Chinese Prehistoric Eyed Bone Needles: A review and assessment. *Journal of World Prehistory, 33,* 385-423. https://doi.org/10.1007/s10963-020-09144-2

Xu, H. A. (1990). There were no bronze sewing needles in the Bronze Age. *Academic Monthly, 1,* 68. https://doi.org/10.19862/j.cnki.xsyk.1990.01.012

Zou, J. H. (2015). *Principles and design of modern sewing machines*. Beijing: China Machine Press.

Notes

Note 1. To determine whether the needles unearthed from a tomb are embroidery needles, the main criteria rely on the associated relationship with other artifacts found in the tomb and the structural and dimensional characteristics of the needles. If a significant number of textile tools (spinning wheels, spindles, loom parts, fabrics) are found accompanying the needles, and the shape of the needle corresponds to that of embroidery needles, then it can be determined that they are indeed embroidery needles.

Note 2. Bone needles unearthed from sites such as the Zhaoge Village Site in Muping, Shandong Province, the Nanshangan Site in Ningcheng County, Liaoning Province, and the Kashahu Stone Coffin Tomb in Luhuo, Sichuan Province, are mostly in the range of 60-85 mm in length. The proportion of shorter needles, around 30 mm has further increased. The width of the bone needles is concentrated in the range of 1-3.5 mm, with the smallest ones measuring only 1 mm in width.

Note 3. Three bone workshops were discovered in Niucun, indicating a highly developed bone tool industry that played an important role in the social-economic production of that time.

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Authors contributions

Prof. Longdi Cheng, Dr. Yunying Liu and Miss Shuai Xu were responsible for study design and revising. Miss Shuai Xu was responsible for data collection. Miss Shuai Xu drafted the manuscript and Dr. Lan Ge revised it. All authors read and approved the final manuscript.

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Obtained.

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