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Adding a New Dimension to Woodwind Instrument Making, With a Little Help from Our (Tech) Friends

Stefaan Verdegem and Ricardo Simian

Researchers who study historical wind instruments often find their work made more difficult, as museums and some private collectors do not allow their instruments to be played.

The question of allowing instruments to be played has been a matter of discussion for many decades. On one hand, it is felt that blowing warm, moist air into an antique instrument may damage it and should be avoided, as recommended by CIMCIM.[1] On the other hand, it is felt that musical instruments are intended to be played and to sound and should continue to be played, albeit under controlled conditions. A famous example is the Bate Collection at Oxford University, where students are allowed to play (and even borrow) many of the instruments. Different collections have a range of guidelines between these positions.

Some collections do not even allow researchers to measure instruments. In many cases where measurement is allowed, metal measuring instruments are forbidden, as it is felt that these could damage the wood. In some cases, even plastic tools may not be used as it is felt that these are also capable of damage if used incorrectly.

The main problem for would-be makers of reproductions is that, by excluding data like pitch, intonation, and sound quality from a research process, this specific and intrinsic information is lost to the researcher; if an instrument cannot be played it is impossible to determine its usable pitch or its sound and playing characteristics and qualities. If an instrument cannot be measured, then it cannot be copied.

1. The CIMCIM (Comité international pour les musées et collections d'instruments et de musique / International Committee for Museums and Collections of Instruments and Music) published some musical instrument handling guidelines: http://cimcim.mini.icom.museum/wp-content/uploads/sites/7/2019/01/Newsletter_10_1982.pdf; see pp. 31–2.

Until recently, musicians, scholars, and instrument makers traveled the world to see and, if allowed, try original instruments in collections and museums, and would eventually copy an instrument that seemed to fulfil the maker's needs in the best way. In the case of woodwind instruments, copying these exactly in the traditional way (using a lathe and reamers, for example) is sometimes impossible because of deformation that affects many wooden objects over time, including distortion of the bore. These irregular bore shapes can be measured but cannot be copied, either with traditional or modern wood machining techniques. Also, if one copies an original, it is often difficult to get feedback from the original artifact after copying it.

Since the beginning of the early music movement employing historical instruments, musicians and instrument makers have been searching collections for "ideal" historic examples to copy. Over time, the early music world developed for itself a kind of canon of instruments that are best to copy, for use in specific repertoire. This practice arose because developing new prototypes of historical woodwinds is time-consuming and can be costly if many reamers have to be made; sometimes these reamers are produced, tried, and used just one time (because they are not good enough), resulting in a significant waste of time and money.

New possibilities have recently become available through 3D printing techniques, which allow the production of very accurate prototypes and experiments in a quicker and cheaper way, without the need for reamers. In a familiar first step, one measures the instrument as fully as possible, often by hand;[2] these data are entered in a computer file which can be printed mirroring the original, or from which a flexible 3D model can be extracted.

The quality of the 3D-printed model and its properties will depend on the accuracy of the measurements, but also on the chosen printing method and material. A large palette of printing methods and materials is available in 3D printing, from sandstone to glass; finding the correct printer and medium for the project at hand is crucial. Plastic polymers are not the only option, but they tend to be more accessible, flexible, and cost-effective, all good reasons for their general use in this area. In addition to their precision, well-chosen polymers can even have a similar inner

2. Electronic and digital techniques to measure the bore exist, but these devices often cannot be used for an oboe's top joint, with its minimal bore of 4–6mm.

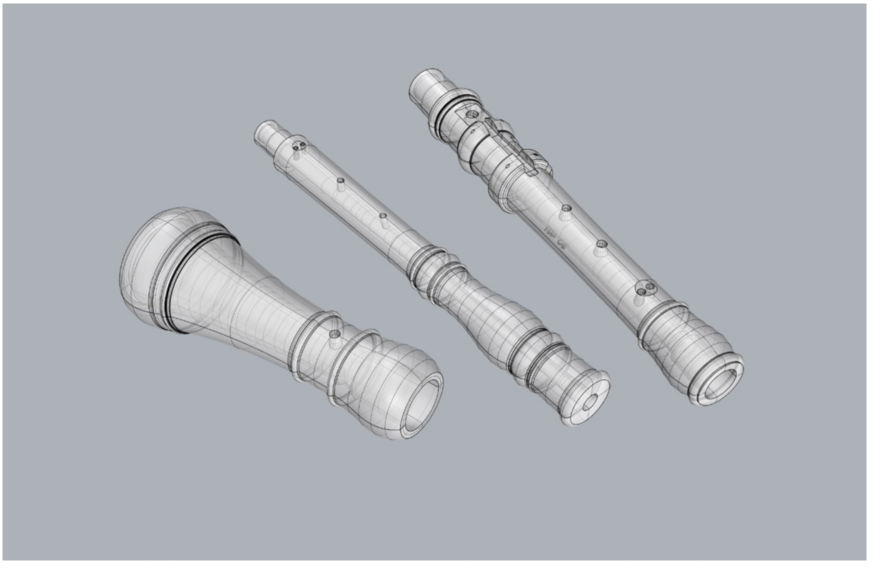


FIGURE 1. 3D-rendering of the I. C. E. Sattler oboe (Leipzig, first half of the eighteenth century). Robert Howe Collection, USA.

structure and density to some woods. A downside is that the polymers react differently to traditional woodworking techniques if modifications are made by hand.

Ideally, a CT (computed tomography) scan of the original artifact is made. Such a CT file can be processed in a computer, but often requires a great deal of work before a printable file can be produced. A practical problem is that these costly CT scanners are not generally found in museums. As a workaround, museums sometimes arrange to use hospitals' CT scanners during night-time hours. In one case, a museum even had to choose whether to assemble or disassemble the 3-joint woodwind instrument (the latter being ideal for printing purposes) before putting it under the scanner, as only one scan could be afforded.

The advantages of this 3D printing approach are many. Developing a prototype and adjusting it is only a matter of adapting the computer file and making a new print. The technology allows the making of new prototypes easily, quickly and at reasonable cost; hardwood timber is preserved, and the 3D-printed musical instrument imitates the wooden one very closely. Eventually it can be used as a professional performance instrument, which is already the case for some instrument types.

Once there is a full measurement or a CT scan, the original instrument

(a) (b)

FIGURES 2a–b. (a) I. C. E. Sattler oboe (Leipzig, first half of the eighteenth century). Robert Howe Collection, USA. (b) 3D-printed copy by Ricardo Simian of the same instrument, after a hand-made measurement drawing. Brass keys added by Marcel Ponseele.

can be spared most further measurement. A future possibility is that collections and museums could make or provide 3D-printed copies for testing, or put the scan data online, allowing anyone to print a copy of a museum instrument at home. We can literally transform certain high-resolution scans into printable models with two or three clicks. It does not work every time, it does not apply to every scan format, and you need a good software and computer to pull off the trick (and maybe a little bit of experience with the settings). But we have done it dozens of times for a project regarding fagottini copies last year.

Full CT scans, consisting of many very high resolution "slices" of the object, are enormous: several gigabytes of data. These files can be difficult to process or even to open without suitable software and computer equipment, and even then are difficult to manage. However, a processed 3D model for printing can be just a few megabytes and can be opened and printed with standard open-source software. Large and free databases for ready-to-print 3D models already exist and the same could be done with museum instruments without the need for any technological upgrade.

Case Study: Fourteen Leipzig Bach Oboes (1720–1750)

A recent research project about the "Bach oboe" by the authors resulted in a series of 3D-printed models that served as study objects next to the original instruments.[3] The 3D-printed instruments represent the pitch and playing characteristics and qualities of the original instrument, insofar as the measurement data represent this original. Most of the 3D prints were based on hand-measured drawings with an accuracy of 0.1mm; metal keys were applied to the printed body. In one case, an incomplete measurement could be completed and tested. In another case (involving an ovalized bore), a change of bore measurements from the horizontal plane to the vertical plane was only a few clicks away, whereas in real instrument making new reamers would be costly—if farmed out—and time-consuming. This flexibility saved time and money, as the first attempt resulted in an unplayable oboe. In a few cases, the prints helped to assess instruments that were remote or inaccessible. In case of a Bauer oboe (MIR376 from

3. Stefaan Verdegem & Marcel Ponseele, "Fourteen Leipzig Oboes from the time of Bach," *The Galpin Society Journal* 74 (2021): 70–102.

the Germanisches National Museum in Nuremberg), a CT scan could be obtained and printed out after disassembling the three joints in the scan file.

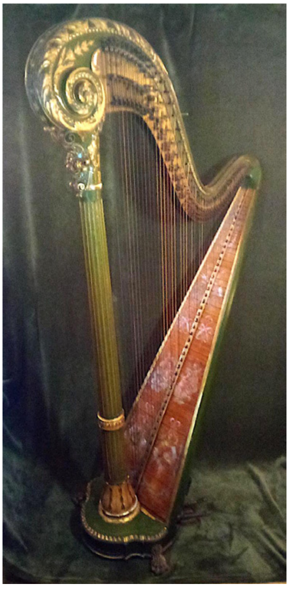
In addition to the many available materials and models of 3D printers, there are different 3D modeling languages. The most common 3D models for printing are produced with Standard Tessellation Language or Stereo-Lithography (STL), which is generated by defining a surface through many small triangles. The smaller and more numerous the triangles, the more precise and smoother the surface, like pixels on screens. With this language, however, it is difficult to introduce modifications, which in some cases require modifying thousands of tiny individual triangles. On the other hand, a 3D model can also be defined in terms of geometrical shapes and functions. In fact, most 3D modeling software operates in such way; one does not create a sphere by drawing millions of small triangles following a spherical shape, but by simply defining the radius of it. Geometric shapes can be easily modified, but no software will automatically generate them from a complex object like a musical instrument. This task requires some human 3D modeling work, making smart use of the available measurements. This can become completely unfeasible if the geometries are too irregular.

Musical instruments, and particularly historical ones, are difficult objects to reproduce; they may look quite regular but, in reality, they are full of irregularities which may or may not be important. It may be desirable to eliminate a crack when making a copy, but this irregularity will be very laborious to remove if the 3D model was directly extracted from a CT scan, which will certainly copy it in full detail; CT scans were developed to find small cracks and clots in our bodies. Moreover, the musical quality of the instrument can depend on a small detail, such as the irregular undercutting of the holes in a hand-tuned wind instrument, and such small irregularities are very difficult to model as geometric shapes. 3D-modeling software is improving, and some options intermediate between "small triangles" and "geometric shapes" are being developed. But this is not yet an area where a casual user can expect to produce an acceptable outcome, in the sense that easily available photo editing software allows user-friendly manipulation of 2D images.

At the beginning of this article, we asked the philosophical question of whether historical instruments are brought to life when they can be played and thus allowed to vibrate. We may also ask: Are 3D-printed musical instruments alive? Also: Are the 3D models of these same musical instruments alive themselves? And: Is a very intricate and irregular 3D model, which mirrors every crack of a museum oboe, more alive than a model with a smoothed-out surface?

These are not no longer merely philosophical questions, as we can now print real objects using these models, to be played and tested, to be presented to audiences, to make comparisons, and to carry out blind tests. The future of musical-instrument research and instrument development will certainly take place within this evolving field, which increasingly unites traditional methods and new technologies.

The following communication has been received from Paul Knoke:
The latest addition to the Paul Knoke harp collection is a Louis XVI model by Erard et Cie, Paris. The harp, shown at left below, is decorated in a Beaux-Arts interpretation of the late Rococo style, its soundboard painted with trophies of musical instruments, plump cherubs, and nesting doves. The rest of the instrument is lavishly carved, and finished with gilding and two tones of green lacquer, powdered with gold dust.



Built in 1901, the harp was purchased by Enrico Tramonti (shown at right with the same harp), then professor of harp at the Geneva Conservatory. Tramonti brought the harp to America for a solo tour and in 1902 took the position of solo harp with the Chicago Symphony Orchestra. After Tramonti retired in 1927, the Erard was purchased by Mildred Dilling, an eminent harpist and collector. Nino Novellino, a Broadway set designer and properties maker, bought the harp from her estate, and kept it until his death in 2021. Knoke plans on restoring the instrument to playing condition.

Paul Knoke is a harpist and AMIS member residing in Rochester, New York. His name was misspelled in a book review in JAMIS 2021, which the editors regret. At our request, he provided this note, of likely interest to readers.

The following communication has been received from Herbert Myers: In his article "The Beginnings of the Violin Bow: Distinctive Capped Specimens for a New Instrument (this JOURNAL, 47 [2021], 5–28), Daniel Crespo Alcarria presents an impressive array of iconographic examples documenting the existence of a peculiar form of violin bow in the early seventeenth century—a form characterized by a short extension of ivory or bone to the bow's tip. But, as the author himself points out, the development of the violin family took place in the early sixteenth century; it thus seems odd to claim that the instrument was in any sense "new" during the period these pictorial examples were produced.

Alcarria's first pieces of evidence for this distinctive development are not, in fact, iconographic; they are two surviving bows in the Kunsthistorisches Museum in Vienna that may stem from just a little earlier. These are two of eleven bows ascribed to the sixteenth century by Rudolf Hopfner, cataloger of the museum's bow collection; the other nine have the more familiar pike's-head tip.[1] Most of these came to the museum from the Este collection, begun in the late sixteenth century by Pio Eneo Obizzi I and once housed in Catajo Castle near Padua. But it is also possible they date from somewhat later, since the collection was added to by later owners, and there is no documentation of these bows from the period.[2] (While Hopfner specifies only the general term "sixteenth century" for all these Este collection bows, it is evident he has "late sixteenth century" in mind, since he suggests they reflect the "rising musical standard" of the century's closing years.[3] His basis for this characterization of the period is unclear.)

It is evident that Hopfner has accepted as original the current method of hair attachment of the two bows in question, in which the hair is fixed to the small, tenon-like projections at the tip.[4] Alcarria points to Robert Seletsky's claim that these bows are missing their ornamental caps, which

1. Rudolf Hopfner, *Streichbogen* (Vienna: Kunsthistorisches Museum and Hans Schneider, 1998), 47–82.

2. The fact that evidence of the pike's-head tip is rare before the seventeenth century lends weight to this later dating of the Este collection bows.

3. Hopfner, *Streichbogen*, 47. He also assumes—without citing any evidence—that these bows were meant for members of the viola da gamba family.

4. Hopfner, *Streichbogen*, 48 and 50. Viewing the current form of attachment at the tip as representative of an archaic practice, he speculates that the hair might originally have been attached in similar fashion at the other end as well, and that the current provision for clip-in frogs might then have been the result of a retrofit. He presents no direct evidence for such a theory, however.

would have both covered the hair at its place of attachment and given the bows better balance.[5] I can only concur with Seletsky that there is an element missing here, since I cannot imagine a maker with the expertise to produce such carefully crafted bow sticks would be happy with the rather "scruffy" appearance associated with the exposed form of attachment. But I cannot agree with his idea that the missing element is a simple cap. Having rehaired a number of such bows, I do not know a way the small post could act as both a pin for attaching the hair and a tenon to anchor a cap; the hair, along with the wrappings of thread necessary to gather it together, simply takes up too much room. And even if one could find a way to attach such a cap firmly, it would have to be inordinately large in diameter to cover the wrapped "knot" at the end of the hair, which of necessity extends beyond the perimeter of the end of the stick. (Alcarria seems not to understand the geometry here when he refers—p. 25—to the hair exiting the cap "through the same socket drilled for the insertion of the bow stick"; that socket would be longitudinal, of course, whereas the hair would have to exit through a lateral hole.) I believe the only viable solution would be one where the hair is attached directly to the cap, using a mortise and plug (as in what we now regard as "standard" practice for bows).

This is, in fact, what we see in Alcarria's next examples of physical evidence: three bows in the Danish Music Museum, Copenhagen. All three have ivory or bone extensions to the tip, all with mortises for the attachment of the hair; all have a provision at the other end for a clip-in frog. As reported by Alcarria, two of the three are dated 1600–1800 by the museum; for the third, there is no dating suggested. Despite this information, and with no explanation offered, Alcarria repeatedly (pp. 14, 24, and 28) groups these three bows with the two Vienna examples as being of sixteenth-century provenance. But a perusal of the large collection of iconographic examples contained in Brigitte Geiser's study of the early history of the violin[6]—a source apparently unknown to Alcarria—reveals little if any support for such a dating; of dozens and dozens of pictures of violins and related instruments, whose associated bows exhibit a great variety of shapes, rates of curvature, and other design features, I see none from the sixteenth century that show

5. Robert Seletsky, "New Light on the Old Bow—1," *Early Music* 32 no. 2, 286–96 (here 286). Hopfner (*Streichbogen*, 48) mentions a similar idea, claiming that iconographic sources frequently show ball-shaped ornamental caps on the ends of bows. I am unacquainted with the sources he is referencing.

6. Brigitte Geiser, *Studien zur Frühgeschichte der Violine* (Bern and Stuttgart: Verlag Paul Haupt, 1974).

anything resembling these examples from Copenhagen. Given that the majority of his iconographic examples were produced by Dutch or Flemish painters during the first few decades of the seventeenth century, statements like the following from Alcarria (p. 24) are particularly puzzling: "The broadly dispersed geographical origins of the respective paintings confirm a widespread use of bows with an ornamental cap on the head, accompanying the violin from its very birth."[7]

There are a few matters of vocabulary and terminology that need to be addressed; here, I believe, better choices would make Alcarria's points clearer. On p. 8 he claims "the curvature [of the bow] became smooth"; I presume he means by this that the curvature was reduced. On p. 12 he mentions a "small screw" on the frog end of one of the Copenhagen bows; I think he is referring here to an ornamental "button," since a bow with clip-in frog would, of course, not possess a screw. (Later—pp. 27 and 28—he uses the correct term "button.") On pp. 12 and 25 he speaks of a "cleat" inserted into the mortise to secure the hair, and on p. 23 he refers to it as a "wedge"; the proper term would be "plug." Finally, just a couple issues of fact: the tenon-like projections on the tips of the two Vienna bows missing their finials are cylindrical (or nearly so), not conical (p. 9). And in mentioning the "horn-shaped nut" serving as a frog on early seventeenth-century bows, David Boyden says nothing about its being of metal (as claimed by Alcarria on p. 8).[8]

Despite these criticisms, I believe Alcarria is very much to be thanked for assembling such a large group of iconographic examples attesting to the existence of a remarkable and significant model of violin bow. One can only wish he had been more careful in dealing with the chronology of this development.

HERBERT MYERS

7. Alcarria cites one early sixteenth-century picture that he believes shows a spherical wooden knob at the tip of a bow—Giovanni Bellini's *Sacra conversazione*, 1505, in the Church of San Zaccaria, Venice. However, I see nothing to indicate the round termination seen on this lira da braccio bow represents a separate appurtenance.

8. David Boyden, *The History of Violin Playing from its Origins to 1761* (London: Oxford University Press, 1965), 114.

The following communication has been received from Daniel Crespo Alcarria:

I thank Dr. Myers for the detailed critique of my article.[9] I see, however, that certain aspects need further explanation. One of the pillars on which my research is based is the use of iconographic material to support it, which is why the use of images from the seventeenth century is justified in the submitted Spanish version of the article:

> Aunque nacido en el siglo XVI (el violín) como todo nuevo instrumento hasta que se consolidad y extiende su empleo, hay un periodo de tiempo en el que la iconografía sigue mostrando mayoritariamente instrumentos anteriores cronológicamente pero ya consolidados, como rabeles o liras, de ahí que el contexto histórico artístico que nos atañe aglutina artistas principalmente del siglo XVII.

This sentence appeared in shortened form on p. 14 of the published article.

Dr. Myers provides a historical introduction about the origin of the early violin bows held in the collection of the Kunshistorisches Museum in Vienna, previously described by Hopfner, and addresses aspects of how the hair is held fast in these bows, which I explained in my article on p. 9. Dr. Myers writes in note 4 that Hopfner "speculates that the hair might originally have been attached in similar fashion at the other end as well, and that the current provision for clip-in frogs might then have been the result of a retrofit. He presents no direct evidence for such a theory, however." But Hopfner in fact provides a clear explanation of the matter:

> Most of the frogs . . . are probably additions. It is not possible to determine when they were made, but two dates seem possible: if the nuts were lost before 1892, it is very likely that they were added on the occasion of the International Exhibition of Music and Theater. It is also conceivable that Alfred Coletti, purveyor to Archduke Franz Ferdinand, who owned the East Collection at the time, made the additions when the stringed instruments in the collection were being restored in 1910.[10]

9. Daniel Crespo Alcarria,"The Beginnings of the Violin Bow: Distinctive Capped Specimens for a New Instrument," this JOURNAL, 47 (2021), 5–28.

10. Rudolf Hopfner, *Streichbogen: Katalog: Sammlung alter Musikinstrumente und Sammlungen der Gesellschaft der Musikfreunde in Wien* (Tutzing: Hans Schneider, 1998), 47. "Bei der Mehrzahl der Steckfrösche zu den Bogen dieses Kapitels dürfte es sich um Ergänzungen handeln. Warm diese vorgenommen wurden ist nicht festzustellen, es erscheinen jedoch zwei Termine möglich: Falls die Frösche bereits vor 1892 verloren gingen, ist eine Ergänzung

Regarding my understanding of geometry, I described in my article two possible ends for capped bows: one in which the hair exits before the insertion of this element (as in the Vienna examples) and another in which the hair exits from the cap itself (as in the Copenhagen examples). As for the doubts Dr. Myers raises about the Vienna bows, visiting the exhibit room where they are displayed will allow a viewer to verify that the posts or tenons at the tips of the bows are small enough, even when wrapped with the hair and thread, to be inserted into a decorative finial cap,[11] even if the form of attachment is considered "scruffy." A walk through San Zaccaria in Venice, where Bellini's *Conversazion* is held (note 45 of my article), would serve to clear up any doubts with respect to the head, that the hair exits before the spherical knob.

It is true that I did not provide a date for the third of the Copenhagen bows (here I say it should also be dated between 1600 and 1800, as the museum dated the other early bows cited). If I group them with those of the Vienna collection, it is because of the peculiar finial cap.

With regard to the iconographic examples by Dutch or Flemish painters cited, historians, performers, and builders have relied on paintings of the Dutch Golden Period and the prolific musical instruments as a source for the music of the time.[12] The degree of detail with which the artists of the period depicted violin bows allows us to recognize and analyze this minuscule characteristic (the cap of the bow). Relevant iconographic evidence also appears in the works of the Italian painters Guido Reni, Niccolò Renieri, and Giovanni Bellini, and in Memling's *Christ Surrounded by Singing and Music-making Angels*, also known as the Santa María la Real de Nájera Altarpiece (fig. 22 of my article).[13]

The vocabulary corrections offered by Dr. Myers are to be appreciated. But if we are being punctilious about the curvature of a bow (my p. 8),

anläßlich der Internationalen Ausstellung für Musikund Theaterwesen sehr wahrscheinlich. Denkbar ist auch daß Alfred Coletti, Kammerlieferant Erzherzog Franz Ferdinands, des damaligen Eigentümers der Sammlung Este, anläßlich einer 1910 erfolgten Restaurierung der Streichinstrumente der Sammlung die Ergänzungen vornahm."

11. Crespo Alcarria, "The Beginnings of the Violin Bow," fig. 1.

12. Magda Kryrova,"Music in the Seventeenth-Century Dutch Painting," in *Music and Painting in the Golden Age*, (Zwolle: Waanders, 1994), 31.

13. Elías Tormo, "Las tablas memlingianas de Nájera, del Museo de Amberes: su primitivo destino, fecha y autor," *Mélanges Bertaux: Recueil de Traváux* (Paris: De Boccard, 1924), 300–322.

"flatter" is Dilworth's original term.[14] On p. 12, the Spanish term for Dr. Myers's "ornamental button" is "tornillo ornamental,"[15] hence the terminological confusion. A similar situation arises with respect to Dr. Myers's "plug," where I wrote "taco de madera" (which appeared in translation as "wedge" and "cleat). These technical terms can be difficult to translate.

In relation to the correction on p. 9 ("conical" versus "cylindrical," or nearly so), I could refer the reader to the reference of Mr. Antonio Crespo Aguado, "Ajustando el cucurucho,"[16] where aspects of both terms are clearly explained. Finally, I have to admit that there is indeed nothing in Boyden's quote about a metal frog.

I thank Dr. Myers once more for his meticulous reading of my article, and I hope I have been able to alleviate some doubts that may have arisen.

Daniel Crespo Alcarria

The editors are responsible for the translation of Mr. Crespo Alcarria's article and this communication, both submitted in Spanish. The editors welcome these comments (from both foregoing writers) and any others that serve to advance understanding of musical instruments.

14. Robin Stowell, ed., *The Cambridge Companion to the Violin* (Cambridge University Press, 1992, 24.

15. An element of adornment that serves to embellish and that should not have a functional use; but literally "ornamental screw."

16. Antonio Crespo Aguado, "Ajustando el cucurucho," *Actas del XI Congreso Internacional de Ingeniería Gráfica: Logroño-Pamplona. 2, 3 y 4 junio* (1999), vol. 1: 357–68.