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A 1:1 Physical Representation and Exploded-View Presentation of Selected Components of the Second Iron Hand of Götz von Berlichingen

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Abstract

Background/Objectives: The second iron hand of the Franconian Imperial Knight Götz von Berlichingen represents a historically significant and mechanically sophisticated example of an upper-limb prosthesis. Its internal mechanism, documented by Christian von Mechel in 1815, comprises articulated phalanges, springs, locking levers, pins, and additional components integrated within the hand corpus. A previous study reconstructed the internal finger mechanics using three-dimensional computer-aided design (3D-CAD), finite element method (FEM) analysis, and a functional prototype at an enlarged scale of 2:1. The present study has a different and narrower objective: to produce a nominal 1:1 physical representation of selected components derived from that previously published CAD reconstruction and to present them in an exploded-view display. The work addresses visualization and protection of the display model rather than mechanical actuation or conservation of the historical artefact. **Methods:** Existing 3D-CAD data from the previously published 2:1 reconstruction were uniformly scaled by a factor of 0.5 using Autodesk Inventor Professional 2027. Preliminary fabrication was performed using fused deposition modeling (FDM) with polylactic acid (PLA). Because the preliminary prints did not reproduce the smallest features with sufficient visual definition, resin-based additive manufacturing was used for the final components. The components were arranged in an exploded-view configuration on a black acrylic-glass backing plate, with a transparent cover, wooden frame, LED illumination, labels, and a separate historical image display. **Results:** The selected CAD components were scaled to nominal 1:1 dimensions and incorporated into the display. The assessment of the two printing approaches was qualitative; no measurements of printed-part dimensional error, surface roughness, repeatability, or mechanical performance were collected. Resin printing was judged visually more suitable for the intended display than the preliminary FDM trial. **Conclusions:** The work provides a physical representation of selected components from a previously reconstructed CAD model. It does not establish the exact dimensions of the surviving historical prosthesis, demonstrate a complete 1:1 reproduction, or validate a functional mechanism. The display has potential for teaching and exhibition, but its educational effectiveness has not been evaluated.

Keywords: Götz von Berlichingen; second iron hand; historical prosthesis; 3D-CAD reconstruction; physical reconstruction; 1:1 representation; resin 3D printing; additive manufacturing; prosthetic history; medical engineering

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1. Introduction

The development of artificial limbs extends over several centuries and encompasses a wide range of mechanical and technological approaches [1]. Among the historically significant examples of early mechanical upper-limb prostheses are the iron hands associated with the Franconian Imperial Knight Götz von Berlichingen (1480–1562) [2,3]. Berlichingen lost his right hand following a cannon-ball splinter injury in 1504 during the War of the Succession of Landshut. A first iron hand was subsequently produced [2], followed several years later by a second prosthesis [3] incorporating a substantially more sophisticated mechanical design.

The second iron hand is particularly notable because its individual fingers could be passively moved at multiple joints and maintained in selected positions through an internal mechanical system [3]. Christian von Mechel documented the prosthesis in 1815 after receiving permission from the von Berlichingen family to dismantle and examine it [4]. His publication contains detailed illustrations of both the external appearance and internal construction of the prosthesis. The fingers comprise several articulated phalanges and incorporate springs, pins, and locking mechanisms that permit positioning and subsequent release [4]. Mechel's documentation provides an important historical basis for modern digital reconstruction. However, the interpretation of the historical drawings is not always unambiguous. Some internal components are shown only partially or from selected viewpoints, and the available documentation does not provide all dimensions and mechanical details required for an unequivocal reconstruction [4,5]. Schneider et al. therefore developed a three-dimensional computer-aided design (3D-CAD) reconstruction of the internal mechanics and investigated selected mechanically stressed components using finite element method (FEM) analysis [5]. Because of the small dimensions of the internal components, the initial physical reconstruction was produced at a scale of 2:1. The resulting prototype enabled important aspects of the proposed mechanical principle to be examined physically [5]. The previous work also identified a significant challenge associated with reproducing the mechanism at its historical scale. In particular, the miniature spring and locking components became mechanically vulnerable when produced at 1:1 scale using the investigated polymer additive-manufacturing approach [5]. The previous study consequently suggested alternative materials and manufacturing methods, including metal fabrication, as potential approaches for a future functional 1:1 reconstruction [5]. Other investigations have demonstrated the potential of digital reconstruction and additive manufacturing for studying and communicating historical iron hands associated with Götz von Berlichingen [6]. These studies illustrate how digital models and physical replicas can provide access to mechanical structures that are difficult to understand from historical illustrations alone.

The objective of the present study differs from that of the previous reconstruction [5]. Rather than developing or mechanically validating a fully functional 1:1 prosthesis, this work transfers selected components of the previously reconstructed geometry to a nominal 1:1 physical representation and presents them in an exploded-view configuration. The contribution is therefore primarily the physical realization and display of selected components at approximately their reconstructed original scale, not a new historical reconstruction or a new validation of the mechanism.

The specific objectives were therefore to:

1. Transfer the previously reconstructed 2:1 CAD geometry to a nominal 1:1 representation;
2. Investigate the suitability of additive-manufacturing approaches for physically reproducing the small reconstructed components at this scale;

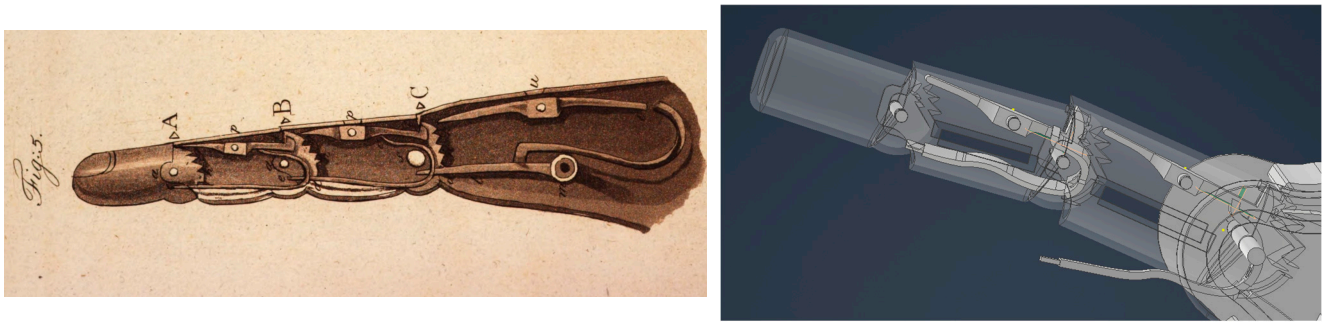
3. Present the components in an exploded configuration that makes their mechanical relationships visually accessible;
4. Integrate the reconstructed components into a protected and transportable exhibition unit together with a historical representation of the original prosthesis.

The resulting model should be understood as a nominal 1:1 physical representation of previously reconstructed CAD geometry, not as a new measurement-based reconstruction of the surviving historical prosthesis. The original source material contains incomplete views and does not provide all dimensions or mechanical details required for an unambiguous reconstruction [4,5]. Consequently, interpretations made when the earlier CAD model was developed—including inferred geometry where the historical illustrations are incomplete—are inherited by the present model. The precise assumptions for individual features are those documented in reference [5]; they were not independently re-evaluated in the present study.

2. Materials and Methods

2.1. Basis of the Physical Representation

The starting point for the present study was the existing 3D-CAD reconstruction of the second iron hand reported by Schneider et al. [5]. The previously developed digital models represented selected components of the internal mechanism at a scale of 2:1, including elements of the finger mechanisms and components located within the hand corpus (Figure 1). The components shown in the display were selected to make a range of otherwise concealed internal elements visible in a compact exploded-view presentation. The selection was display-oriented rather than an attempt to represent every component of the complete mechanism; no formal ranking or exhaustive component-selection matrix was used.



(**a**) (**b**)

Figure 1. Historical second iron hand of Götz von Berlichingen and schematic overview of the reconstructed internal mechanism. (**a**) Original finger [4]; (**b**) Reconstructed finger.

No new historical reconstruction was performed in the present study. The previously published CAD geometry was used as the direct geometric basis for the physical representation, and no new historical dimensions were established. The earlier reconstruction relies on interpretation of von Mechel's drawings, in which some internal components are shown only partially or from selected viewpoints and not all dimensions and mechanical details are available [4,5]. The present study did not independently resolve these ambiguities; all assumptions and interpretations incorporated into reference [5] are retained.

This approach distinguishes the present work from the previous study [5]. Whereas the previous work focused on reconstructing and investigating the proposed mechanical principle using an enlarged functional prototype, the present work focuses on the visual presentation of selected components at nominal 1:1 CAD scale. No functional 1:1 mechanism was assembled or tested.

2.2. Scaling from 2:1 to 1:1

The CAD models were processed using Autodesk Inventor Professional 2027 (Autodesk, Inc., San Rafael, CA, USA). Each selected component was uniformly scaled by a factor of 0.5, thereby converting the previously reconstructed 2:1 geometry to a nominal 1:1 representation.

Following scaling, the models were inspected in Autodesk Inventor for geometric features potentially affected by conversion, with particular attention to holes, wall thicknesses, small structural features, and other dimensions relevant to fabrication. The dimensions in Table 1 were compared between the original 2:1 CAD models and the scaled CAD models. These are CAD-derived dimensions only: the printed components were not measured against the CAD models, and dimensional error, printer accuracy, and feature-specific deviations were not quantified.

Table 1. Representative dimensions taken from the 2:1 CAD models and the corresponding CAD dimensions after uniform scaling to nominal 1:1. Values are calculated from the CAD geometry and are not measurements of the historical artefact or of the printed components.

Component	Feature	2:1 CAD	1:1 CAD	Reduction (%)
Housing element	Width	116.00 mm	58.00 mm	50
	Height	71.00 mm	35.50 mm	50
	Wall thickness	2.50 mm	1.25 mm	50
	Largest hole diameter	6.20 mm	3.10 mm	50
	Upper Fillet radius	25.60 mm	12.80 mm	50
Head of the phalanx B	Wall thickness	2.50 mm	1.25 mm	50
	Curved Grooves	60°	60°	0
Housing locking lever	Wall thickness	1.00 mm	0.50 mm	50

No independent modification of the historical geometry was introduced during this process. Features were not enlarged solely to compensate for anticipated limitations of the printing process. The objective was to preserve the geometry of the previously published reconstruction as far as practicable.

The resulting models therefore represent nominal 1:1 versions of the previously reconstructed CAD geometry. The scale designation describes the CAD scaling operation; it does not indicate that the printed parts were metrologically verified or that their dimensions independently match the surviving historical prosthesis.

2.3. Additive Manufacturing

2.3.1. Preliminary FDM Fabrication

The initial manufacturing approach was fused deposition modeling (FDM). Preliminary fabrication was performed using a Prusa MK3S/MK3S+ printer (Prusa Research, Prague, Czech Republic) with a nominal build volume of 250 × 210 × 210 mm^3 and a 0.4-mm nozzle.

Polylactic acid (PLA) was initially selected as the printing material. A representative small component containing small structural features and thin walls was used for a preliminary trial. The purpose was to assess whether the investigated FDM setup could reproduce the geometry with sufficient visual definition for the display, not to establish general limits of FDM manufacturing. The printer model and 0.4-mm nozzle are reported above; other FDM settings, including layer height, print speed, temperature, and orientation, were not systematically recorded for this comparison.

In the preliminary FDM prints, small features were insufficiently defined, some thin structures appeared fragile, and the surface showed a comparatively coarse appearance.

These observations were visual and qualitative. Because the trial used a single nozzle size and was not a systematic parameter study, the results do not establish that FDM is generally unsuitable; different settings or equipment may produce different outcomes.

These characteristics were considered unsuitable for the intended presentation because the purpose of the physical model was to make small mechanical components visually distinguishable rather than to demonstrate the mechanical performance of the printed material.

2.3.2. Resin-Based Fabrication

The final components were produced using a Phrozen Sonic Mega 8K printer (Phrozen Technology, Hsinchu City, Taiwan), with a build volume of 330 × 185 × 400 mm^3 and a 405-nm light source. The resin used was ecoResin (3DJAKE, light grey). A layer height of 0.05 mm was used. Exposure times were 36 s for the first three burn-in layers, decreasing linearly to 1.4 s by layer 18 and remaining constant thereafter. Part orientation and support placement were chosen case by case to support delicate components while avoiding visible support marks on cylindrical outer surfaces. The manuscript records these general principles but does not provide a component-by-component orientation/support map. After printing, components were allowed to drip for 15 min, washed in isopropanol for 15 min, dried for 15 min, and cured for 40 min at room temperature under 365-nm and 405-nm UV light at 100% intensity. Exact irradiance values were not available. No printer-specific dimensional tolerance or minimum reliably reproducible wall thickness was measured or established in this study; such values should not be inferred from the nominal layer height alone.

The resin-based process was selected because the resulting components appeared to reproduce fine features more clearly and had smoother visible surfaces than the preliminary FDM prints. This was a qualitative workshop assessment rather than a controlled comparison. No dimensional measurements, surface-roughness measurements, repeatability assessment, or mechanical tests were conducted. The Edu FabLab/workshop facilities of Offenburg University supported printing and post-processing. The project team supplied the scaled CAD data, coordinated print preparation, and assessed the components for visual presentation.

2.4. Assessment of the Manufacturing Result

The printed components were assessed primarily with respect to their suitability for visual representation of the reconstructed geometry. The assessment focused on:

1. Reproduction of small geometric features;
2. Preservation of overall component geometry;
3. Visible deformation or incomplete reproduction;
4. Surface quality;
5. Structural integrity during handling and mounting; and
6. Suitability for presentation within the intended showcase.

The comparison between FDM and resin-based fabrication was qualitative and application-oriented. It was not a controlled comparison of materials or processes, and no quantitative measurements of dimensional accuracy, surface roughness, repeatability, or mechanical properties were made.

2.5. Design Requirements for the Showcase

The presentation unit was developed according to predefined functional and visual requirements. These requirements were:

1. Representation of the selected reconstructed components at nominal 1:1 scale;

2. Protection against dust and accidental mechanical contact;
3. Transportability;
4. The possibility of reopening the enclosure without permanent destruction;
5. Clear visual separation of individual components; and
6. Improved visibility under different ambient lighting conditions.

The showcase requirements included protection against dust and accidental contact, the ability to reopen the enclosure, visual separation of components, and illumination intended to aid visibility. A morphological design approach was used at a conceptual level to consider enclosure, mounting, illumination, and labeling. However, no formal morphological matrix, documented set of alternative concepts, or scored screening procedure was retained. The final configuration consisted of a vertically oriented showcase with a transparent acrylic-glass front, black acrylic-glass rear panel, screwed wooden side panels, adhesive component mounting, and integrated LED illumination. The design process should therefore be understood as a practical selection of a final configuration rather than a fully documented morphological analysis.

2.6. Exploded-View Presentation

The selected nominal 1:1 components were arranged on a black acrylic-glass rear panel measuring 426 × 330 × 3 mm^3. They were not assembled into a functional mechanism but were spatially separated in an exploded-view configuration to expose internal elements that would otherwise be concealed. Phalanges, pins, springs, locking levers, and housing elements were positioned to suggest their approximate spatial relationships and to permit individual viewing. The layout is for visualization only and does not represent an assembled or operational state. The display contains selected components, not a complete reproduction of the entire hand mechanism.

2.7. Construction of the Showcase

The side structure of the showcase consisted of four wooden panels with nominal dimensions of 420 × 130 × 8 mm^3 and 340 × 130 × 8 mm^3, respectively. The panels were manufactured using a computer numerical control (CNC) milling process. Two continuous grooves measuring 4 × 4 mm were incorporated into each side panel to accommodate the front and rear acrylic-glass panels. The wooden side panels were connected using screws rather than permanent adhesive joints. This construction permits the enclosure to be reopened if components, labels, or other elements require replacement or modification. A transparent acrylic-glass panel was used as the front cover. The cover provides physical protection while maintaining direct visual access to the reconstructed components. The black rear panel provides visual contrast with the printed components.

2.8. Illumination

The showcase was equipped with a battery-powered LED lighting system. Natural-white LEDs were positioned along the upper and lateral inner surfaces, and a narrow white plastic strip was placed in front of them to reduce direct visibility of the light sources. The arrangement was intended to aid visibility of the components under different ambient lighting conditions; illumination levels and any improvement in visibility were not measured. The battery compartment was mounted externally on the rear to permit battery replacement without opening the enclosure.

2.9. Historical Reference Presentation

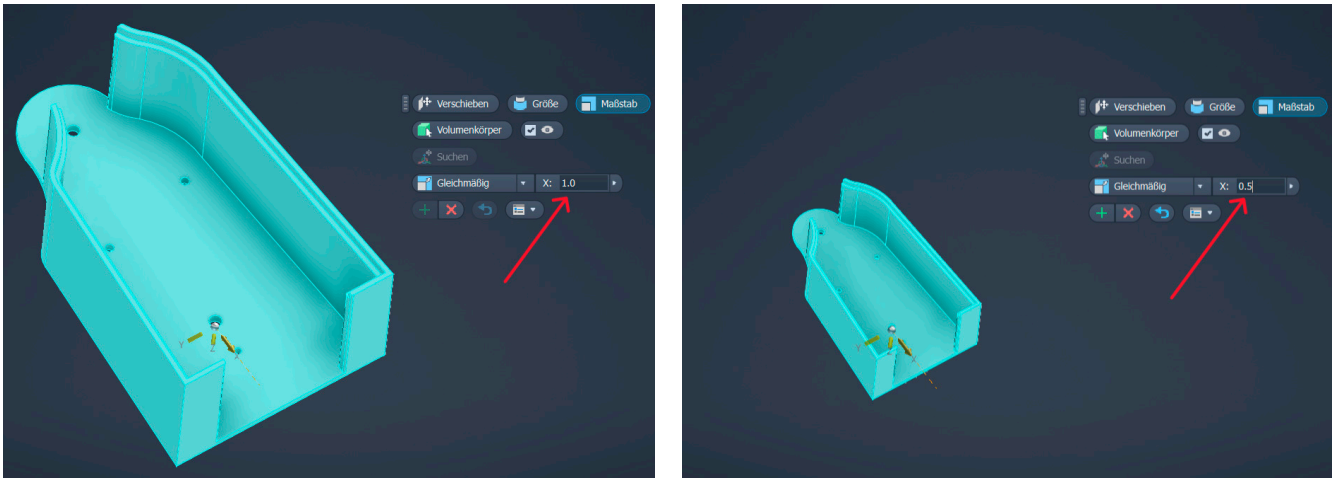
A separate display stand containing a historical image of the second iron hand was produced as a contextual reference [4]. The purpose of this element was to establish a visual

connection between the complete historical prosthesis and the individual reconstructed mechanical components. The final presentation therefore comprises two complementary levels: the historical image provides information about the overall form and historical context of the prosthesis, whereas the exploded-view model provides a physical representation of selected internal mechanical components. The historical image was used as a reference rather than as evidence that every dimension of the physical model corresponds exactly to the surviving historical prosthesis.

3. Results

3.1. Transfer of the CAD Reconstruction to Nominal 1:1 Scale

The selected components of the previously published 2:1 CAD reconstruction were scaled by a factor of 0.5 to produce nominal 1:1 CAD models (Figure 2). The CAD inspection found no features that prevented proportional scaling, and no corrective geometry changes were introduced. Table 1 reports representative dimensions before and after scaling. These values verify the arithmetic of the CAD scaling operation only; because the printed parts were not measured, the results do not establish the dimensional accuracy of the physical components.

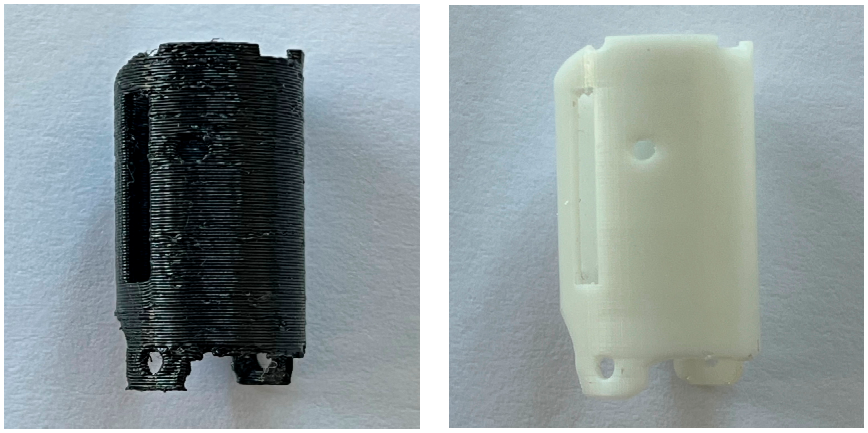


(**a**) (**b**)

Figure 2. Representative CAD geometry before and after scaling from 2:1 to nominal 1:1 scale. (**a**) Original 2:1 reconstruction; (**b**) scaled 1:1 representation.

3.2. Comparison of Additive-Manufacturing Approaches

In the preliminary FDM trial using a 0.4-mm nozzle, small features were less clearly defined and the surface appeared coarser than in the resin-printed examples. Resin-printed components were judged visually more suitable for the intended display (Figure 3). This observation is limited to the specific preliminary setup and was not supported by measurements of dimensional accuracy or surface roughness. No conclusion can be drawn about the general superiority of resin printing, and no quantitative comparison of mechanical properties or repeatability was performed.



(**a**) (**b**)

Figure 3. Qualitative visual comparison of one representative component produced by (**a**) FDM fabrication using PLA and (**b**) resin-based fabrication. No dimensional or surface-roughness measurements were performed.

3.3. Physical Representation of the Internal Mechanics

The resin-printed selected components were arranged in an exploded-view configuration. The display includes reconstructed phalanges, connecting pins, springs, locking elements, and components associated with the internal hand mechanism. Components are spatially separated for visualization while retaining approximate spatial relationships. The arrangement exposes parts that would otherwise be concealed in an assembled prosthesis, but it is not a functional assembly and does not demonstrate the mechanism in operation (Figure 4).

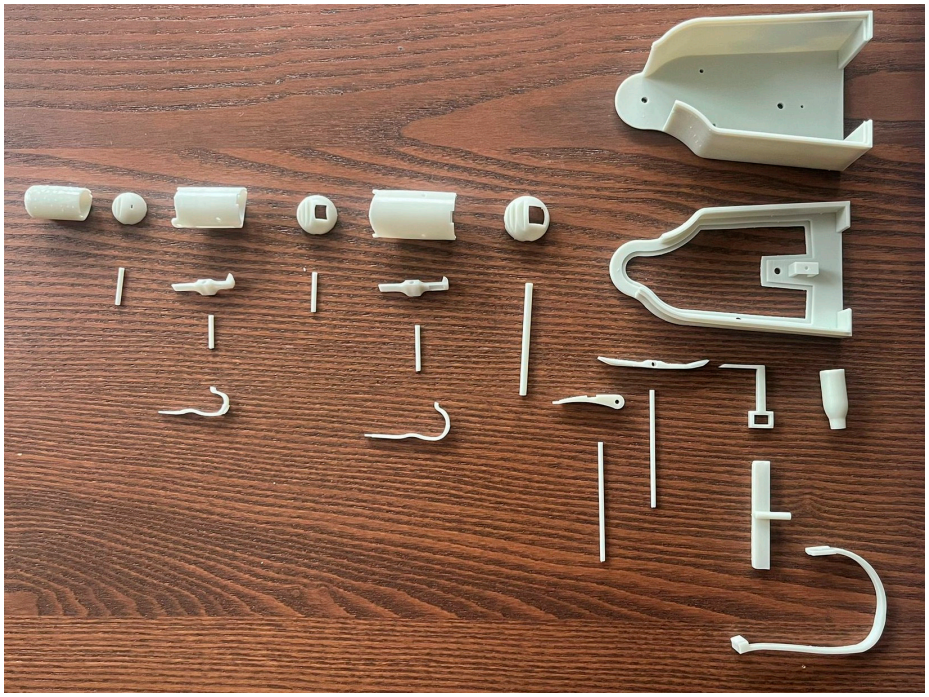


Figure 4. Exploded-view arrangement of selected components of the second iron hand. Components are spatially separated to aid visualization; the arrangement does not represent an assembled or operational state.

3.4. Completed Showcase

The completed showcase includes a transparent front panel, a black rear panel, labels, and integrated LED illumination (Figure 5). The transparent cover is intended to reduce accidental contact with the printed components, while the black backing provides visual contrast. Screwed wooden side panels allow the enclosure to be reopened for access or modification. The unit was designed to be transportable, but transport durability was not formally tested. The LED arrangement was intended to aid visibility; no lighting measurements or user evaluation were conducted.

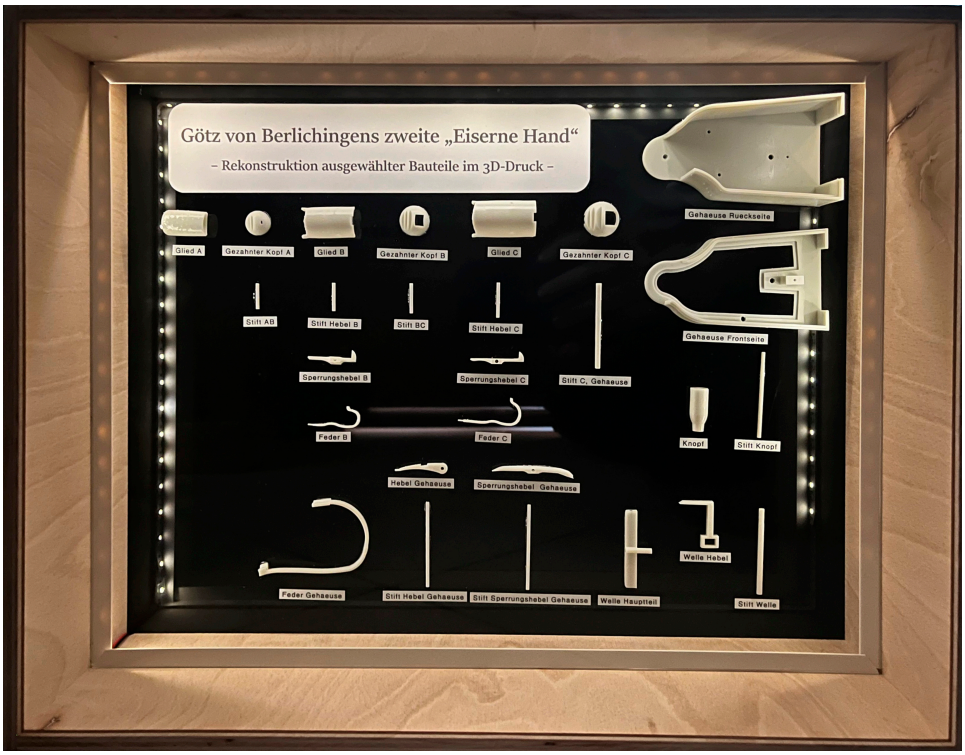


Figure 5. Completed showcase containing selected nominal 1:1 CAD-derived components. The transparent front panel, black rear panel, labels, and LED lighting are visible; transportability and lighting performance were not quantitatively evaluated. English translations of the shown German designations of the individual components are provided in the section *Abbreviations*.

3.5. Integration with the Historical Reference

The historical image display provides contextual information about the complete second iron hand and establishes a visual relationship between the external prosthesis and the reconstructed internal components [4]. The resulting presentation combines two complementary forms of representation (Figure 6). The historical image provides information about the overall form and historical context of the prosthesis, whereas the exploded-view model provides access to selected mechanical components that are normally concealed within the assembled hand. The combination therefore enables the viewer to relate the individual reconstructed components to the overall historical prosthesis without requiring the internal mechanism to be inferred exclusively from historical drawings.

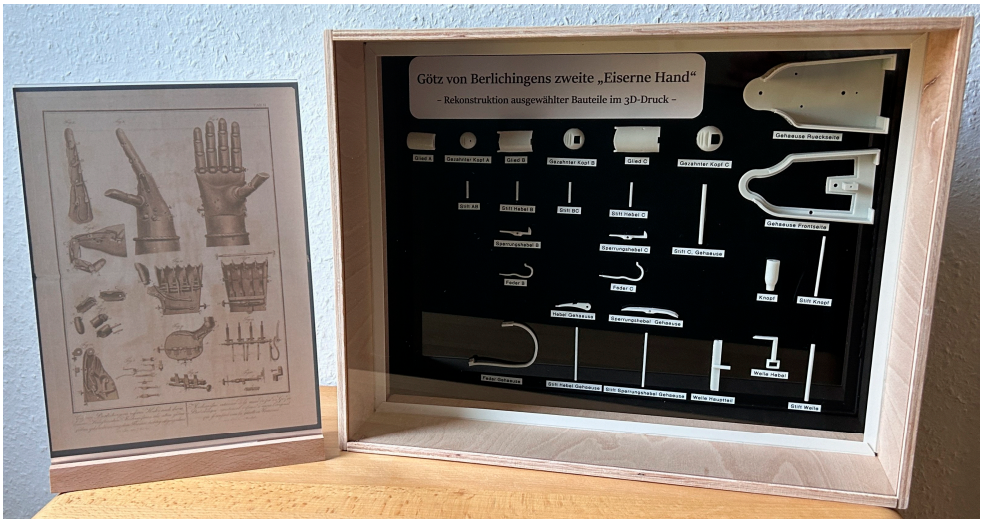


Figure 6. Historical reference image shown alongside the physical display of selected CAD-derived components. The image provides historical context and does not validate the dimensions of the printed components.

4. Discussion

The present study provides a physical display of selected components derived from the previously published 2:1 CAD reconstruction of the second iron hand [5]. Its contribution is the transfer of selected CAD geometry to nominal 1:1 scale and the development of an exploded-view presentation, rather than a new reconstruction of the historical mechanism. The earlier study investigated the proposed mechanical principle, including FEM analysis and a functional 2:1 prototype [5]. The present study does not establish a new mechanical model, validate the historical geometry, or demonstrate a functioning 1:1 mechanism.

This distinction is important because a direct 1:1 functional reproduction of the reconstructed mechanism presents substantial manufacturing challenges. The previous study demonstrated that some mechanically loaded components, particularly the miniature spring, were highly susceptible to mechanical failure when produced at reduced dimensions using polymer additive manufacturing [5]. The present study does not attempt to overcome these mechanical limitations. Instead, the manufacturing process was selected according to the requirements of geometric reproduction and visual presentation.

4.1. Manufacturing at the Original Scale

The preliminary FDM trial suggested that the tested setup did not reproduce the smallest features as clearly as the resin workflow. Because the FDM comparison used a preliminary trial with a 0.4-mm nozzle and did not systematically vary print settings, it cannot establish that FDM is categorically unsuitable. Layer height, speed, temperature, and other settings were not recorded sufficiently to support a reproducible parameter comparison.

Resin printing produced visually clearer fine features and smoother-looking surfaces in the components assessed. These findings are based on visual inspection only. The study did not measure dimensional deviations, surface roughness, minimum reproducible feature size, or repeatability; therefore, no quantitative printer tolerance or minimum wall-thickness capability can be reported.

However, the improved geometric reproduction should not be interpreted as evidence of improved mechanical suitability. The resin-printed components were not subjected to mechanical loading or durability testing. The choice of resin printing was therefore driven

by the requirements of visual representation rather than by the objective of producing a mechanically functional prosthesis.

Different reconstruction objectives may consequently require different manufacturing strategies. A functional replica requires materials and manufacturing processes capable of reproducing the mechanical behavior required by the mechanism. A visualization-oriented model can instead prioritize geometric reproduction, surface quality, handling, and visual accessibility.

4.2. Interpretation of the 1:1 Scale

The nominal 1:1 scale is particularly relevant for understanding the mechanical complexity of the second iron hand. The enlarged 2:1 prototype reported previously facilitated examination of the mechanism and supported physical investigation of its functional principle [5]. However, enlargement inevitably changes the apparent size of individual components.

The present model provides an opportunity to observe the reconstructed components at approximately their original dimensions. This makes the physical scale of the individual phalanges, pins, springs, and locking elements more immediately apparent.

The nominal 1:1 scale must be interpreted in relation to the reconstruction process. The components were obtained by uniformly scaling the previously published 2:1 CAD reconstruction rather than by independently measuring the surviving historical prosthesis. The original documentation contains incomplete views and does not provide all dimensions or mechanical details [4,5]. Interpretations and assumptions in the earlier reconstruction are consequently retained. The present study did not re-evaluate the geometry against the historical artefact.

The present model should therefore be understood as a nominal 1:1 physical representation of the previously reconstructed geometry, rather than as definitive evidence that every component corresponds exactly to the dimensions of the surviving historical prosthesis.

4.3. Value of the Exploded-View Configuration

The exploded-view presentation provides an alternative to a conventional assembled functional model. In an assembled prosthesis, many technically relevant components are concealed within the phalanges and hand corpus. A functional model can demonstrate movement and mechanical interaction, but it does not necessarily provide optimal visual access to the internal construction.

The present arrangement deliberately separates the components while maintaining their approximate spatial relationships. This makes individual mechanical elements visible and allows the observer to examine their relative arrangement without dismantling the model.

This approach is particularly appropriate for a historically reconstructed mechanism because the internal construction is an important part of its technological significance. Mechel's original publication already attempted to document this construction through technical illustrations [4]. A physical three-dimensional exploded representation provides an additional means of communicating the same information.

The exploded-view configuration should not be interpreted as an actual operating state. Components are intentionally separated for visualization, and their arrangement is intended to communicate approximate constructional relationships rather than reproduce the assembled geometry during operation. The display does not demonstrate functional interaction among the components.

4.4. Relationship to Previous Reconstructions

The present work forms part of a broader series of investigations into the iron hands associated with Götz von Berlichingen [5,6]. Previous studies have addressed historical interpretation, digital reconstruction, mechanical analysis, and physical reproduction of these prostheses.

The current contribution is limited to transferring selected elements of the previously reconstructed second iron hand from an enlarged 2:1 CAD model to a nominal 1:1 physical display. The principal changes are scale and presentation purpose, not the underlying historical or mechanical reconstruction. No printed-part dimensional validation or mechanical validation was performed.

The 2:1 reconstruction enabled mechanical investigation and functional demonstration [5]. The current 1:1 representation instead prioritizes physical scale, visibility of internal components, and long-term presentation.

The two models consequently address different objectives. The earlier model was primarily concerned with whether the reconstructed mechanism could function, whereas the present model addresses how the reconstructed mechanism can be physically represented and communicated at approximately its original size.

4.5. Potential Application for Teaching and Exhibition

The physical model may serve as a resource for teaching and exhibition in prosthetic technology, medical engineering, mechanical design, and the history of artificial limbs. This is a potential application rather than a demonstrated educational outcome.

The display makes selected components that are normally hidden within the assembled prosthesis directly visible. Combining the historical image with the exploded-view display may help viewers relate the overall historical object to the interpreted internal structure; this benefit has not been assessed with users.

No formal educational or user evaluation was conducted. Therefore, the study provides no evidence about learning effectiveness, visitor comprehension, or educational benefit.

The model should instead be regarded as a potential teaching and exhibition resource. Future work could investigate whether physical exploded representations improve understanding of historical prosthetic mechanisms compared with conventional photographs, drawings, or digital models.

4.6. Limitations

Several limitations should be considered.

First, the physical model is derived from the previously published 2:1 CAD reconstruction [5] and inherits its assumptions and uncertainties. The original historical illustrations do not provide every dimension or an unambiguous view of every internal feature [4,5]; the present study did not independently verify inferred geometry against the surviving artefact.

Second, the 1:1 models were intended for visualization rather than mechanical operation. The resin material and printed components were not mechanically characterized or subjected to cyclic loading. Consequently, the present study provides no evidence regarding the ability of the printed components to reproduce the mechanical performance of the historical prosthesis.

Third, the FDM–resin comparison was qualitative and based on visual suitability for the intended display. No systematic measurements of dimensional accuracy, surface roughness, minimum reproducible feature size, mechanical strength, or repeatability were performed. Printer-specific tolerance and minimum reliable wall thickness were not established. The

FDM trial used a 0.4-mm nozzle, but other process settings were not documented as a controlled parameter study.

Fourth, the showcase features—including transportability and the intended benefit of LED illumination—were not evaluated through formal durability, lighting, or user tests. The educational and exhibition value has likewise not been formally assessed.

Finally, only selected components of the complete mechanism were represented. The selection was made for display and visualization rather than completeness, and the model is not a complete 1:1 reproduction of the second iron hand.

These limitations define the scope of the present work and distinguish it from a future mechanically functional 1:1 reconstruction.

4.7. Future Work

Future work could address reconstruction, manufacturing, and evaluation. A complete 1:1 reconstruction would require consideration of components not included in the present display and further investigation of materials suitable for mechanically loaded miniature parts. A component inventory and explicit selection rationale would also improve reproducibility of the present display.

In particular, the spring and other components subjected to significant mechanical loads represent potential candidates for high-precision metal manufacturing. Metal additive manufacturing, precision machining, or hybrid manufacturing approaches could be investigated to determine whether a mechanically functional 1:1 reconstruction is feasible.

Further work could include dimensional measurements of printed components against the CAD models; a controlled comparison of printing technologies and settings; reporting printer-specific tolerances and minimum reproducible features; durability and illumination tests of the showcase; and an evaluation of educational usefulness with students or visitors.

A combination of a mechanically functional model and an exploded visualization model could ultimately provide complementary representations of the historical prosthesis: one demonstrating its mechanical operation and the other exposing its internal construction.

5. Conclusions

This study produced a physical display of selected mechanical components derived from the previously published 2:1 CAD reconstruction of the second iron hand of Götz von Berlichingen. The CAD geometry was uniformly scaled to nominal 1:1 dimensions, and selected components were produced using resin-based additive manufacturing for an exploded-view presentation. The study's contribution is the physical visualization and display of selected components at approximately their reconstructed original scale, not a new historical reconstruction or a functional 1:1 mechanism. The comparison between FDM and resin printing was qualitative; no printed-part dimensional accuracy, surface roughness, repeatability, or mechanical performance was measured.

The display may be useful for teaching and exhibition, but its educational effectiveness has not been evaluated. The CAD-derived dimensions should not be interpreted as measurements of the surviving historical prosthesis, and the printed components were not mechanically validated. Future work should include dimensional validation, systematic manufacturing comparisons, and assessment of the display with users.

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Data Availability Statement: The CAD data used in this study were derived from previously developed reconstruction data reported in ref. [5]. The CAD files generated and used for the present physical representation are not publicly available.

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Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

3D-CAD	Three-dimensional computer-aided design
FDM	Fused deposition modeling
FEM	Finite element method
PLA	Polylactic acid
German and English designations of the individual components are provided below:	
Glied A	Finger segment A
Gezahnter Kopf A	Ratchet head A
Stift AB	Pin AB
Glied B	Finger segment B
Stift Hebel B	Pin lever B
Sperrungshebel B	Pawl B
Feder B	Spring B
Gezahnter Kopf B	Ratchet head B
Stift BC	Pin BC
Glied C	Finger segment C
Stift Hebel C	Pin lever C
Sperrungshebel C	Pawl C
Feder C	Spring C
Gezahnter Kopf C	Ratchet head C
Stift C Gehäuse	Pin finger segment C–housing
Gehäuse Rückseite	Rear housing shell
Gehäuse Frontseite	Front housing shell
Knopf	Button
Stift Knopf	Button pin
Feder Gehäuse	Housing spring
Hebel Gehäuse	Housing lever
Stift Hebel Gehäuse	Housing lever pin
Sperrungshebel Gehäuse	Housing pawl
Stift Sperrungshebel Gehäuse	Housing pawl pin
Welle Hauptteil	Main shaft
Welle Hebel	Lever shaft
Stift Welle	Shaft pin

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