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Geometric Absolutism in Renaissance Typography: A Calligraphic Analytical Perspective on Luca Pacioli's De Divina Proportione

Abstract

Luca Pacioli's De Divina Proportione (1509), one of the foundational texts that laid the geometric groundwork of Renaissance typography, systematizes the period's quest for universal harmony and mathematical perfection through letterforms. But how does this geometric absolutism relate to the dynamic nature of calligraphy? Guided by this question, this article aims to reevaluate Pacioli's understanding of "geometric absolutism"—rooted in the discipline of compass and ruler—from the analytical and applied perspective of a Latin calligrapher. Employing a qualitative Arts-Based Research design, the Pacioli alphabet, predominantly addressed in the literature within the contexts of art history or graphic design, is analyzed here through the tension between the dynamic nature of calligraphic execution (ductus) and the static construct of geometric form. Within the scope of this research, the letterforms idealized by Pacioli were manually reproduced using traditional calligraphic techniques; the ontological discrepancies arising in the relationship between pen angle, its movement across the surface, and ink flow with geometric grid systems were evaluated through systematic observation and comparative analysis. The findings reveal how letter anatomy based on mathematical proportions is reinterpreted in calligraphic practice through optical balance, bodily intuition, and the margin of human error. This article argues that the rationalization process in Renaissance typography was not a rupture from the calligraphic tradition, but rather a sophisticated form of integration developing between the two disciplines. The study is limited to Pacioli's 23 uppercase letters, with in-depth analysis confined to the letters "A" and "O".

Keywords: Luca Pacioli, de Divina Proportione, Latin calligraphy, geometric absolutism, Renaissance typography, ductus.

Rönesans Tipografisinde Geometrik Mutlakiyet: Luca Pacioli'nin De Divina Proportione Eseri Üzerine Kaligrafik Analitik Perspektif

Özet

Rönesans tipografisinin geometrik temellerini atan metinlerin başında gelen Luca Pacioli'nin 1509 tarihli De Divina Proportione adlı eseri, dönemin evrensel uyum ve matematiksel mükemmellik arayışını harf formu üzerinden sistematikleştirir. Peki bu geometrik mutlakiyet, kaligrafinin dinamik doğasıyla nasıl bir ilişki kurar? Bu sorudan hareket eden makale, Pacioli'nin pergel ve cetvel disiplinine dayalı "geometrik mutlakiyet" anlayışını, bir Latin kaligrafi sanatçısının analitik ve uygulamalı perspektifinden yeniden değerlendirmeyi amaçlamaktadır. Nitel araştırma yaklaşımına dayalı Sanat-Temelli Araştırma (Arts-Based Research) deseniyle yürütülen çalışmada, literatürde çoğunlukla sanat tarihi veya grafik tasarım bağlamında ele alınan Pacioli alfabesi, kaligrafik icranın dinamik doğası (ductus) ile geometrik formun statik kurgusu

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arasındaki gerilim üzerinden analiz edilmiştir. Araştırma kapsamında, Pacioli'nin idealize ettiği harf formları geleneksel kaligrafi teknikleri kullanılarak manuel olarak yeniden üretilmiş; çalışma, Pacioli'nin 23 büyük harfinden "A" ve "O" harfleriyle sınırlandırılmıştır. Kalemin açısı, yüzey üzerindeki devinimi ve mürekkep akışının geometrik kafes sistemleri ile kurduğu ilişkide ortaya çıkan ontolojik uyumsuzluklar değerlendirilmiştir. Çalışmanın bulguları, matematiksel oranlara dayalı harf anatomisinin kaligrafik pratikte optik denge, bedensel sezgi ve insani hata payı ile nasıl yeniden yorumlandığını ortaya koymaktadır. Bu makale, Rönesans tipografisinde rasyonelleşme sürecinin kaligrafik gelenekten bir kopuş değil, aksine iki disiplin arasında gelişen sofistike bir entegrasyon biçimi olduğunu savunmaktadır.

Anahtar Kelimeler: Luca Pacioli, De Divina Proportione, Latin kaligrafisi, geometrik mutlakiyet, Rönesans tipografisi, ductus.

INTRODUCTION

The Cosmic Order of the Renaissance: The Intersection of Mathematics and Art

The Renaissance represents one of humanity's pinnacle endeavors to comprehend the universe through mathematical precision and reconstruct this order via visual forms. Art functioned not merely as aesthetic expression but as knowledge production, rendering universal order visible through proportion and geometry. This thought system, flourishing in Italy from the mid-fifteenth century, synthesized Ancient Greek and Roman mathematical heritage with Christian theology, transforming visual arts into a terrestrial reflection of "divine order." This relationship between mathematical thought and artistic production became particularly pronounced in theoretical approaches to writing and letterforms (Wittkower, 1971; Panofsky, 1955).

Artists and thinkers sought the mathematical structure underlying the universe. Nicholas of Cusa (1401-1464) argued that "abstract geometric forms" signified God's perfection, influencing period art theorists (Cusanus, 1440/1985). Leon Battista Alberti (1404-1472), in De Pictura (1435), articulated perspective and mathematical proportion as proof that art was an intellectual pursuit, not merely manual skill (Alberti, 1435/1991).

Letters, like architectural structures, became "sacred" forms to be constructed according to mathematical proportions. However, this quest for "geometric absolutism" introduced an ontological question: How does the static discipline of compass and ruler reconcile with the dynamic motion of the pen (ductus)? Luca Pacioli's De Divina Proportione (1509) emerges as the most competent example systematizing the geometric construction of letterforms, while laying groundwork for rethinking the relationship between calligraphic tradition and rational typography. This article, reevaluating Pacioli's geometric absolutism from a Latin calligrapher's analytical perspective, argues that Renaissance typography's rationalization was not a rupture from calligraphic tradition but a sophisticated integration between the two disciplines.

Luca Pacioli and De Divina Proportione

The Typographic Imagination of a Humanist Mathematician

Luca Pacioli (c. 1445–1517) was a Franciscan friar, mathematician, and one of the most influential figures of Renaissance humanism. Having taught mathematics in major cultural centers such as Perugia, Florence, Milan, and Rome, he was not merely a scholar but also an intellectual advisor to artists on matters of mathematical perspective and proportion. His comprehensive treatise Summa de Arithmetica, published in 1494, systematically compiled the mathematical knowledge of the age and became a foundational resource for artists, architects, and merchants.

"Pacioli’s magnum opus, De Divina Proportione (On the Divine Proportion), originally completed in manuscript form around 1497 and printed in Venice in 1509 by Paganinus de Paganinis, is conventionally described as comprising three principal books or sections: (1) a theoretical exposition of the divine proportion, (2) its applications to architecture, perspective, and letterforms, and (3) an Italian version of Piero della Francesca’s De quinque corporibus regularibus (Wittkower, 1971; Kemp & Wallace, 2019; Pacioli, 1509/2014). The cover of the modern facsimile

edition (see Figure 1) reflects the Renaissance synthesis of mathematical order and visual harmony, with its woodcut border and typographic arrangement embodying the aesthetic ideals of the period.

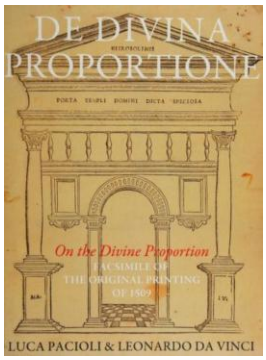

Figure 1 Luca Pacioli and Leonardo da Vinci, "De Divina Proportione: Facsimile of the Original Version of 1509" [Book cover], 2014.

Pacioli's emphasis on the adjective "divine" was deliberate. For him, the golden ratio represented the mathematical manifestation of the sacred order established by God in the universe. The ratio also carried theological significance because of its perceived qualities: a single definition symbolizing unity, a tripartite structure reflecting the Trinity, and a nature grasped through perception rather than reason alone, echoing the mystery of God (Pacioli, 1509/2014). These ideas laid the intellectual foundation for Pacioli's treatment of letterforms as visual embodiments of mathematical harmony.

The Geometric Construction Process in the Shadow of Da Vinci

One of the features that makes De Divina Proportione unique is its collaboration with Leonardo da Vinci (1452-1519), one of the greatest artists of the era. When Pacioli joined the court of Duke Ludovico Sforza in Milan around 1496 as a mathematics teacher, he met Leonardo, who was the court's painter and engineer, and a fruitful friendship began between the two geniuses (Museo Galileo, n.d.; Pisano, 2016). Pacioli taught Leonardo mathematics, particularly Euclid's geometry, while Leonardo contributed illustrations of polyhedra for Pacioli's De Divina Proportione (Huffman, 2017). Their subsequent escape together to Florence following the French capture of Milan in 1499 testifies to the strength of this bond (SparkNotes, n.d.; Cove Collective, 2019).

Leonardo's contribution to De Divina Proportione consists of the illustrations of geometric shapes within the work. The 59 drawings of regular and semi-regular polyhedra at the end of the treatise are masterpieces reflecting both Leonardo's artistic genius and mathematical comprehension (see Figure 2).

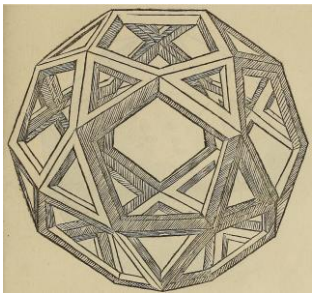

Figure 2 Luca Pacioli, "Regular Polyhedron Drawing from De Divina Proportione," 1509.

These drawings, depicting the solid bodies in both skeletal and solid forms, rank among the most advanced examples of period perspective. However, Leonardo played no role whatsoever in the typographic letter schemes of the work. The typographic letter diagrams were drawn by Pacioli himself (Huffman, 2017). This indicates that Leonardo's contribution was limited solely to the

illustrations of geometric solids and that he did not assume a direct role in the design of the letterforms. Consequently, the Latin alphabet in De Divina Proportione is entirely the product of Pacioli's geometric thinking. This distinction is significant for evaluating the work in terms of typographic history; for the letterforms reflect the aesthetic preferences of a mathematician, not the era's greatest artist.

The Golden Ratio (1.618): A Quest for "Absolutism" in Letter Anatomy

A particularly remarkable section of De Divina Proportione is the appendix dealing with the geometric construction of the uppercase letters (Roman capitals) of the Latin alphabet. In this section, Pacioli constructs each letter using a compass and ruler, placing them within fundamental geometric shapes such as squares and circles (see Figure 3). This alphabet, comprising a total of 23 letters (excluding Z, with O drawn twice), reinterprets the classical forms inherited from Ancient Roman epigraphy through the Renaissance quest for mathematical perfection (Morison, 1972; Wittkower, 1971).

In Pacioli's approach, the 'golden ratio' (approximately 1.618) plays a determining role not only in geometric solids but also in letter anatomy. According to him, just as in the human body and architecture, the beauty of letters depends on capturing this divine ratio. The height-to-width proportions of letters, stem thicknesses, and counter proportions were all determined according to this divine ratio. This understanding represents an effort to define the letterform as an "absolute" and "immutable" mathematical object. Pacioli's quest for this "geometric absolutism" constitutes a turning point in the history of typography; because the letter is now transformed into an ideal form constructed through a mental design process, rather than through the organic movement of the pen (Bringhurst, 2004; Meggs & Purvis, 2016).

Problem Statement: The Conflict Between Ideal Form and Organic Line

However, from the perspective of a Latin calligrapher, a letter is not merely a static geometric construction; it is a dynamic field of performance shaped by the angle of the pen, the flow of ink, contact with the surface, and the rhythm of writing (Johnston, 1906; Goudy, 1940). This writing flow, termed *ductus* in calligraphic practice, determines not only the appearance of the letter but also its "mode of being." The letter is a trace emerging over time through the movement of the pen, the result of an action.

In this context, a structural tension arises between the geometric ideal proposed by Pacioli and calligraphic practice. While the understanding of geometric absolutism freezes the letter on a two-dimensional plane, excluding temporality and movement, calligraphic practice defines the letter as a performance realized over time. Pacioli's mathematical letter construction does not always align with the bodily and intuitive nature of calligraphic practice; in certain cases, it creates a space requiring intervention through optical correction, deviation, and interpretation (Cheng, 2005; Noordzij, 2005).

This study focuses precisely on this area of tension. The fundamental problem of the research is to identify at which points Pacioli's understanding of geometric absolutism overlaps with traditional Latin calligraphy practice, at which points they conflict, and what the ontological sources of this conflict are.

Aim and Significance of the Research

The primary aim of this research is to theoretically examine the letter construction system of the Latin alphabet proposed by Luca Pacioli in his work *De Divina Proportione* (1509) within the framework of the concept of "geometric absolutism," and to reveal, from the analytical perspective of a calligrapher, the relationship this system establishes with traditional Latin calligraphy practice. The study aims to discuss at which points Pacioli's ideal letterforms, based on mathematical proportions, overlap with, conflict with, and under which conditions can be reinterpreted through the bodily, intuitive, and optical dimensions of calligraphic execution.

Accordingly, the research confronts Gerrit Noordzij's theoretical approach, which sees the origin of letterforms in "the stroke," with Pacioli's static geometric grid systems; and, through Michael Polanyi's concept of "tacit knowledge," questions how the artist's bodily intuition stretches this mathematical absolutism. Thus, the ontological tension between the static discipline of the compass and ruler and the dynamic motion of the pen (*ductus*) is analyzed on both theoretical and practical levels.

The significance of the research can be summarized in three main points:

1. **Original Perspective:** It aims to be one of the few studies addressing the mathematical foundations of Renaissance typography directly from the perspective of Latin calligraphic practice. Pacioli's geometric letter construction system has mostly been examined within the context of art history or graphic design and has not been approached with an analytical method based on the first-hand experience of calligraphic execution.
2. **Theoretical Contribution:** The concept of "geometric absolutism" offers an original conceptual contribution to Pacioli literature, proposing a new framework for understanding the philosophical and aesthetic dimensions of Renaissance typography. This concept allows for problematizing the relationship between the period's mathematical understanding of the universe and the material reality of the letterform.
3. **Methodological Innovation:** Adopting the "practice-based research" model as defined by Candy and Edmonds (2018), the study establishes an interdisciplinary bridge between art history and design theory. The manual reproduction of Pacioli's idealized letterforms using traditional calligraphic techniques within the scope of the research provides a methodology that nourishes theoretical discussion directly with practical experience.

This three-dimensional approach is structured to support the central view that the rationalization process in Renaissance typography was not a rupture from the calligraphic tradition but rather a sophisticated form of integration developing between the two disciplines.

Scope and Limitations of the Research

This research contains certain limitations regarding its scope:

- **Geographical and Historical Scope:** The study is limited to typographic theories produced during the Italian Renaissance that focus on the Latin alphabet. Similar approaches developed in other European countries (such as Dürer in Germany, Tory in France) are excluded from the scope.
- **Letter Set Scope:** The study is confined to the 23 uppercase letters (majuscules) drawn by Pacioli in *De Divina Proportione*; lowercase letters (minuscules) and cursive forms are not included.
- **Practice Scope:** The calligraphic reproduction process is limited to specific pen types (broad-edged metal pens), inks, and paper types. Experiments possible with different materials are left for future studies.
- **Interpretation Scope:** The research focuses on the aesthetic and technical dimensions of Pacioli's letters and does not delve into a detailed analysis of the work's mathematical content (polyhedra, ratio theory).

These limitations serve to focus the research and allow for in-depth analysis of the findings obtained.

CONCEPTUAL FRAMEWORK: GEOMETRIC ABSOLUTISM

Geometric Absolutism: The Authority of Compass and Ruler

In Renaissance thought, the compass and ruler were symbols of intellectual authority, mathematical precision, and universal truth. Pacioli's recourse to these instruments while constructing the Latin alphabet expresses the desire to subject the letterform not to the organic movement of the pen but to the immutable laws of mathematics (Eisenstein, 1979).

This study proposes "geometric absolutism" to define Pacioli's approach. Geometric absolutism is based on the belief that a letterform can be defined universally and immutably through geometric shapes (square, circle, triangle) and mathematical proportions (golden ratio, integer ratios). The letter is not the result of an action performed by a specific hand at a specific time but an ideal form product of a mental design process (Tracy, 1986).

The Ontology of the Square and Circle: The Cosmic Grid of the Letter

At the foundation of Pacioli's letter construction system lies a philosophical tradition extending from Antiquity to the Renaissance: the epistemological superiority of the square and circle. The geometric shapes Plato employed in the Timaeus dialogue to explain the creation of the universe were synthesized with Christian theology throughout the Middle Ages, becoming visual symbols of the "cosmic order" (Plato, 360 BC/1977). While the square represented the earthly, the four elements, the four directions, and the stability of the material world; the circle symbolized the celestial, infinity, perfection, and divine order (Eco, 1986).

This phenomenological distinction between the two shapes becomes evident in how Pacioli constructs his letters. The square provides a measurable, rational framework—what Plato would call the noetic (intellectual) dimension—while the circle introduces a perceptual, almost mystical quality that transcends pure measurement. Pacioli used these shapes as a "cosmic grid," but the epistemological weight falls differently: the square grounds the letter in rational geometry, while the circle elevates it toward divine proportion.

Letters are placed within a square, while circular forms are positioned inside or tangent to it. The letter "O" consists of two concentric circles; "A" is constructed with triangular forms inside a square. The letter thus becomes a phenomenological bridge between the measurable and the sacred, the rational and the intuitive (Morison, 1972).

This parallels Renaissance architectural theories. Inspired by Vitruvius, architects visualized the "universal man" (Homo Universalis) by placing the human body within a square and circle. Leonardo's "Vitruvian Man" is the best-known example (Wittkower, 1971). Pacioli's letters, like the Vitruvian Man, render visible the relationship between microcosm and macrocosm—an epistemological claim about how knowledge of the universe can be accessed through geometric form.

Typographic Canons: From Ancient Roman Epigraphy to Renaissance Geometry

Pacioli's system draws from Roman epigraphy but reinterprets it through Renaissance mathematical thought. The Capitalis Monumentalis (Roman capitals), particularly Trajan's Column inscriptions (AD 113), served as the Western writing tradition's fundamental reference (Fairbank, 1970).

Roman epigraphy did not construct letterforms according to a geometric system; forms were shaped by stonecutters' skill. Renaissance humanists sought to discover the mathematical proportions underlying these forms. Felice Feliciano, Damiano da Moille, and Sigismondo Fanti attempted reconstructing Roman letters using geometric methods (Morison, 1943).

Pacioli presents one of the most mature examples. His letters preserve classical Roman forms while binding them to strict geometric rules. Stem thicknesses, serif angles, and counter proportions are determined through the golden ratio or integer ratios (1:2, 2:3, 3:4). This constitutes

one of the first systematic "canonical letter" examples in typography history (Carter, Day & Meggs, 1993).

Rationalized Aesthetics: Is the "Perfect Letter" a Utopia?

Pacioli's geometric absolutism brings philosophical and aesthetic problems. The quest for the "perfect letter" adapts Plato's theory of ideas to typography. Plato believed sensed objects are imperfect copies of ideal forms; true knowledge consists of attaining these ideal forms (Plato, 380 BC/1987). Pacioli similarly believed mathematically definable "ideal" letterforms exist behind seen and written letters.

This Platonic approach was revived by the Florentine Platonic Academy led by Marsilio Ficino (1433-1499), which synthesized Plato's ideas with Christian theology, disseminating the idea that the "divine" manifests in mathematical forms (Kristeller, 1964).

However, this understanding encounters practical problems. First, a geometrically perfect letter may not appear optically perfect. The human perceptual system differs from geometric measurements. Calligraphers and typographers have for centuries preferred optical balance over geometric precision (Tschichold, 1991). Second, the quest for the "perfect letter" risks ignoring historical and cultural diversity of letterforms (Bringhurst, 2004).

Pacioli's quest for the "perfect letter" can be evaluated as a utopia. Like Thomas More's Utopia (1516), Pacioli's ideal letters serve as unattainable guides that show the way as we strive toward them.

Calligraphic Practice and Ductus

Opposing Pacioli's geometric absolutism stands the centuries-old tradition of calligraphic practice, which treats the letter not as a static object but as a dynamic action centered on the concept of ductus.

The Concept of Ductus: The Flow of Ink and Time

Ductus, from Latin "ducere" (to lead, to draw), defines how many strokes a letter is written in, in what order, and in what direction (Johnston, 1906). It shows how a letter exists over time. Noordzij (2005) defines writing as a "moving trace." The letter is not an "object" but an "event." Ductus is the script of this event.

In the calligraphic tradition, ductus is also cultural knowledge transmission. Master calligraphers transmit stroke order and aesthetic results through direct practice within the master-apprentice relationship (Harris, 1995). Ductus is both the technical and cultural memory of writing.

The Language of the Pen: Angle, Pressure, and Rhythm

Three fundamental parameters determine the letterform in calligraphic practice: pen angle, pressure, and rhythm.

Pen angle refers to the angle the pen makes with the paper. With a broad-edged pen, the angle determines stroke thickness and character. Minor deviations during writing give the letter an organic character (Goudy, 1940).

Pressure refers to the force the pen applies to the paper. Fluctuations manifest in ink density, stroke edge roughness, and blot formation. Such "imperfections" give the letter vitality and character (Cheng, 2005).

Rhythm refers to the temporal dimension of writing. A skilled calligrapher, like a musician, moves with a specific sense of rhythm while writing, breathing life into letters (Johnston, 1906).

Optical Correction and the Human Factor

Optical correction is one of calligraphic practice's most important characteristics. The human eye does not always perceive geometrically perfect forms as perfect. Calligraphers have for centuries preferred optical balance over geometric precision (Tschichold, 1991).

These optical corrections are intuitive interventions based on the human perceptual system. This knowledge is "tacit knowledge" transmitted through craftsmanship rather than written rules (Polanyi, 1966). Countless variables—hand trembling, ink flow, paper absorbency, pen wear—make each letter unique. In the calligraphic tradition, these "flaws" constitute the "human" aspect of the letter, giving it soul and character (Sennett, 2008).

The fundamental tension between Pacioli's geometric absolutism and calligraphic practice is the tension between mathematical perfection and human imperfection. Pacioli seeks to elevate the letter to a mathematically definable, reproducible, and immutable ideal form; calligraphic practice treats the letter as a living, breathing entity recreated each time. This dialogue constitutes one of the most productive areas of tension in typography history.

METHODOLOGY: THE CALLIGRAPHIC ANALYTICAL PERSPECTIVE

Research Model: Arts-Based Research

This study is based on the Arts-Based Research (ABR) model within qualitative research approaches. ABR positions artistic practice as a research method, combining the artist's production process with systematic observation and analysis (Barone & Eisner, 2012). The artist operates not merely as a "practitioner" but also as a "researcher" who observes and theorizes their own practice.

The fundamental assumption of ABR is that artistic practice constitutes a unique form of knowledge production. Sullivan (2010) defines this as "visual knowledge"—insights unattainable through traditional academic methods. This study aims to reveal the visual and bodily knowledge emerging during calligraphic reproduction of Pacioli's geometric letters. In this study, the researcher, as a Latin calligrapher with 15 years of professional experience, operates not merely as a "practitioner" but as a "researcher" who systematically observes, documents, and theorizes their own practice. This dual role allows for the generation of tacit knowledge (Polanyi, 1966) that emerges through bodily engagement with materials—knowledge that cannot be fully captured through theoretical analysis alone.

The research model is structured around two interacting axes: theoretical analysis and applied practice. Theoretical analysis examines the historical and philosophical context of Pacioli's work; applied practice observes how theoretical knowledge is embodied during calligraphic execution. This dual structure positions both forms of knowledge with equivalent epistemological value (Candy & Edmonds, 2018).

Theoretical Analysis: Literature Review and Document Analysis

Pacioli's De Divina Proportione was examined using literature review and document analysis within the context of Renaissance art theories, mathematical proportion, and typographic developments. Primary sources include the original 1509 edition (see Figure 3), modern facsimiles, and translations; secondary sources consist of academic studies in Renaissance art, typographic history, history of mathematics, and calligraphic theory.

During document analysis, Pacioli's original drawings were examined in detail. The geometric construction process of each letter was followed step by step, and information was tabulated. Comparative analysis was conducted with other typographic canon studies (Felice Feliciano, Damiano da Moille, Sigismondo Fanti) to identify Pacioli's original contributions. Document analysis followed systematic approaches accepted in the literature (Bowen, 2009).

Figure 3 Luca Pacioli, "Opening Page of De Divina Proportione," 1509.

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The Conflict Between Theory and Practice: Calligraphically Reproducing Pacioli's Letters

Pacioli's geometric letter system is a theoretical construct based on the absolute authority of compass and ruler (see Figure 4). This section treats the applied practice carried out by the author as a Latin calligraphic artist as a field of "conflict" and "negotiation," revealing ontological discrepancies when Pacioli's idealized forms are reinterpreted within calligraphic execution.

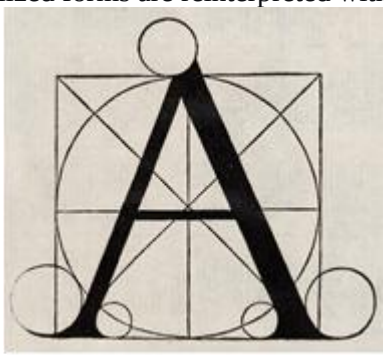

Figure 4 Luca Pacioli, "Method of Constructing Letters with Compass and Ruler in De Divina Proportione," 1509.

The focus is on two letters, "O" and "A," which most clearly represent the tension between geometric form and craft practice. "O" symbolizes geometric perfection, representing the purest application of circular proportion; "A" stands at the intersection of geometric construction and calligraphic execution, embodying the most complex structural challenges. These two letters were selected as extreme cases (Flyvbjerg, 2006) to maximize the visibility of the tension between geometric theory and calligraphic materiality: "O" as the epitome of mathematical purity and "A" as the most structurally intricate form in Pacioli's alphabet.

Materials and Technical Specifications

Standard traditional Western calligraphy materials were used in the applied phase of the research. The selection of materials was guided by the aim of achieving consistency and reproducibility while maintaining authentic calligraphic practice.

Pens: Broad-edged metal nibs (Brause, Mitchell) in three different tip widths (0.75 mm, 1.5 mm, and 3 mm) were employed. The use of multiple nib widths allowed observation of how scale affects the relationship between geometric proportion and calligraphic execution.

Ink: Black, water-based calligraphy ink (Walker's, Higgins) was used for all trials to ensure consistency in flow and density characteristics.

Paper: Smooth surface calligraphy paper, 120 g/m², was selected for its optimal absorbency and surface friction properties, which are critical factors in calligraphic execution (Johnston, 1906; Goudy, 1940).

Auxiliary tools: Compasses, rulers, protractors, and a digital caliper with 0.01 mm precision were used for geometric template preparation and post-execution measurements.

Documentation: The application process was documented using a digital camera (fixed tripod, standardized lighting conditions) and a research notebook containing detailed field notes for each trial. All trials were conducted under consistent environmental conditions (room temperature: 20–22°C, humidity: 40–45%) to minimize external variables.

Application Process and Data Collection

The application process was conducted in three stages. First, Pacioli's original drawings were examined, and geometric construction steps of "O" and "A" were extrapolated. Geometric templates were prepared using compass and ruler.

Second, calligraphic reproduction was carried out based on the templates. A total of 120 trial writings were conducted for each letter (A and O), with 20 trials per pen angle (15°, 30°, 35°, 45°, and 60°). The letters were written repeatedly with different nib widths (0.75 mm, 1.5 mm, and 3 mm) and pen angles; writing speed was also varied (slow, moderate, and fast) to observe its effect on form. Parameters such as pen angle, pressure, and ink density were recorded for each trial.

Third, calligraphic products were compared with Pacioli's geometric templates, examining measurement differences (using a digital caliper with 0.01 mm precision) , ink distribution, and optical effects through visual analysis by the researcher and two independent expert calligraphers for triangulation.

A participant-observer approach was adopted. The researcher is simultaneously practitioner and observer, combining emic (insider) and etic (outsider) perspectives (Spradley, 1980). All trials were documented using a digital camera (fixed tripod, standardized lighting conditions) and a research notebook containing field notes.

Analysis Parameters

Table 1 presents the fundamental parameters and evaluation methods for comparing geometric construction and calligraphic execution. These parameters were selected based on the theoretical framework of calligraphic practice (Johnston, 1906; Noordzij, 2005) and the specific requirements of Pacioli's geometric system. Each parameter addresses a distinct dimension of the tension between geometric absolutism and calligraphic execution: (1) technical parameters (pen angle, pressure, ink density), (2) temporal parameters (ductus), (3) structural parameters (geometric constraints), and (4) perceptual parameters (optical correction).

Table 1. Basic Parameters and Evaluation Methods Used in the Analysis Process

Parameter	Definition	Measurement / Evaluation Method
Pen Angle	The angle the pen makes with the paper plane	Measurement with a protractor; determination of the optimum angle for each letter; 20 trials per angle (15°, 30°, 35°, 45°, 60°)
Pressure	The force the pen applies to the paper	Observation of changes in line thickness; ink density analysis; qualitative assessment of stroke character

Ink Density	The fluidity of ink and its distribution on paper	Examination of line edge roughness, ink spot formation, and tonal differences; visual inspection under standardized lighting
Ductus (Writing Flow)	Stroke order, direction, and continuity of the letter	Stroke count; analysis of transitions between strokes and rhythm; temporal measurement with a stopwatch (in seconds)
Geometric Constraints	Limits determined by the compass-ruler system	Level of compliance with the geometric diagram; measurement of deviations using a digital caliper (0.01 mm precision)
Optical Correction	Interventions aimed at human perception	Visual analysis through expert evaluation; comparison of geometric and optically corrected versions

Source: Created by the author.

The analytical framework includes perceptual and aesthetic evaluation alongside technical measurements. Ductus and optical correction are critical indicators revealing differentiation between geometric system and manual practice. The integration of both quantitative (caliper measurements, protractor readings) and qualitative (visual analysis, expert evaluation) assessment methods ensures a comprehensive understanding of the relationship between Pacioli's geometric ideals and calligraphic materiality.

Data Analysis and Interpretation

Data were evaluated using thematic analysis and comparative analysis techniques. Thematic analysis followed Braun and Clarke's (2006) six-phase model: familiarizing with data, generating initial codes, searching for themes, reviewing themes, defining and naming themes, producing the report. In the coding process, the following themes were identified: (1) technical parameters (pen angle, pressure, ink distribution), (2) perceptual parameters (optical correction, visual balance), and (3) temporal parameters (ductus, rhythm, stroke order). These themes were derived iteratively through multiple readings of the field notes and repeated examination of the calligraphic reproductions.

Comparative analysis systematically compared differences and similarities between Pacioli's geometric diagrams and calligraphic reproductions, including both quantitative (measurable deviations) and qualitative (aesthetic evaluation) dimensions. All quantitative measurements (line thickness, stroke angles, and proportions) were taken three times and averaged to ensure reliability. Qualitative evaluations were conducted through visual analysis of the calligraphic products in comparison with Pacioli's original geometric templates.

Triangulation was employed to increase validity and reliability through:

Data triangulation: Different letters (A and O), different pen widths (0.75 mm, 1.5 mm, 3 mm), different writing speeds (slow, moderate, fast)

Methodological triangulation: Theoretical analysis and applied practice

Researcher triangulation: Self-evaluation as an experienced calligrapher (15 years of professional practice) and independent evaluation by two expert calligraphers (Denzin & Lincoln, 2018). The independent evaluators were provided with both Pacioli's geometric templates and the calligraphic reproductions, and were asked to assess the visual and technical correspondence between the two without prior knowledge of the research hypotheses.

Ethical considerations: All visual materials presented in this study are either the author's original calligraphic reproductions, Pacioli's original drawings (public domain, 1509), or properly cited archival images. No human subjects were involved in this research. The independent expert

evaluators participated voluntarily and provided informed consent for their contributions to be included in the methodology.

FINDINGS: CALLIGRAPHIC ANALYSIS AND INTERPRETATION

Fundamental Principles of Pacioli's Geometric Letter System: A, O, and Other Letters

The Latin alphabet presented by Luca Pacioli in the appendix of his work *De Divina Proportione* (1509) constitutes one of the most systematic expressions in the field of typography of the Renaissance quest for mathematical perfection. At the foundation of the letter system Pacioli constructed with compass and ruler lies the understanding of geometric proportion extending from Antiquity to the Renaissance. Each letter is placed within a specific square (*quadrato*), and the side length of this square determines the height of the letter. The width of the letters, stem thicknesses, and counters are related to this square through the golden ratio (1:1.618) or simple integer ratios (1:2, 2:3, 3:4) (Morison, 1972; Bringhurst, 2004). This approach can be read as the application of Pacioli's understanding of the "divine proportion" to letterforms. In this section, the fundamental principles of the system will be analyzed, particularly through the letters "A" and "O," while other letters will be briefly evaluated within the framework of these principles.

The Letter "A": Pacioli's letter "A" is one of the most complex examples of geometric construction. In the letter placed within a square, two main stem lines rising from the base of the square meet at the top edge, forming the apex. The stem thickness is fixed at 1/10 of the square's side length (Carter, Day & Meggs, 1993). The crossbar of the letter is placed exactly at 1/2 of the height (the center of the square) and has the same thickness as the stems. The ends of the crossbar connect to the stems at right angles. The counter of the letter "A" forms a triangular shape with proportions determined according to the golden ratio (Pacioli, 1509/2014; Wittkower, 1971). With all these features, the letter "A" exhibits architectural solidity and geometric precision (Tracy, 1986).

The Letter "O": The letter "O," the purest example of geometric perfection, consists of the combination of two concentric circles. In the construction, again starting with a square, the largest circle that can be inscribed within the square determines the outer contour. The diameter of the inner circle is determined as 2/3 of the diameter of the outer circle; thus, the thickness of the letter stem equals 1/3 of the outer circle's radius (Pacioli, 1509/2014; Goudy, 1940). Another noteworthy point in Pacioli's "O" is his preference for a slightly flattened form on the vertical axis instead of a perfect circle. This optical correction indicates that geometric precision must be balanced with visual perception (Tschichold, 1991; Cheng, 2005).

Other Letters: Pacioli consistently applied these principles observed in the letters "A" and "O" to the entire alphabet. Letters such as "N", "V", and "H" are constructed with fixed stem thicknesses determined by the 1/10 rule applied to vertical, horizontal, and diagonal lines placed within the square (Morison, 1943; Bringhurst, 2004). While letters "C" and "G" are based on the circular logic of "O", "E" and "F" continue the system of vertical stem and horizontal arms from "H". "M" is a symmetrically extended version of "N"; "P" and "R" are circular forms attached to a vertical stem. The fact that the entire alphabet is designed in majuscule (uppercase) form reflects the humanist interest in Ancient Roman epigraphy (Fairbank, 1970; Meggs & Purvis, 2016).

The fundamental characteristics of Pacioli's geometric system are summarized in Table 2. The table makes the theoretical framework of the system visible by holistically presenting the proportional system, understanding of symmetry, and use of circular structures. This geometric system can be read as the application of Pacioli's understanding of the "divine proportion" to letterforms. However, the extent to which this system overlaps or conflicts with calligraphic practice will be addressed in Section 4.2.1 (Calligraphic Analysis of Letters "A" and "O") and Section 4.3 (Comparative Technical Analysis).

Table 2. Fundamental Features of Pacioli's Geometric Alphabet System

Feature	Description	Example Letters
Placement within square	All letters are placed within a specific square module	Complete letter set
Ratio system	Golden ratio (1:1.618) and simple integer ratios (1:2, 2:3)	A, O, N
Fixed stem thickness	Stem thickness is determined as 1/10 of the square's side	A, N, H, V
Circular forms	Circles and arcs are defined by specific mathematical ratios	O, C, G, Q
Symmetry	Most letters have a symmetrical structure on the vertical axis	A, H, M, O, V
Optical correction	Visual balance is considered rather than geometric perfection	O (slightly flattened); A (angle adjustment)

Source: Created by the author.

Findings of Calligraphic Reproduction

This section presents the findings obtained during the process in which the researcher, in the identity of a Latin calligraphic artist, reproduced Pacioli's geometric letter templates using traditional calligraphic tools. The reproduction process, as detailed in the Methodology section, encompasses numerous trials carried out with different nibs, different pen angles, and different writing speeds. In this section, the findings obtained, particularly through the letters "A" and "O", have been analyzed comparatively, and the fundamental differences observed between the geometric diagram and calligraphic execution have been classified.

Calligraphic Analysis of Letters "A" and "O"

The calligraphic reproduction of Pacioli's geometric "A" has been one of the areas where the tension between theory and practice is most intensely observed. The findings obtained during the reproduction process can be evaluated under four main headings: the pen angle problem, positioning of the crossbar, optical perception of the counter, and sustainability of stem thickness.

Pen Angle Problem: In Pacioli's geometric "A", the stem lines are designed to maintain the same thickness as they rise from the base to the apex. However, when writing with a broad-edged pen, the stroke thickness is directly dependent on the angle the pen makes with the paper. A stroke written at a specific pen angle inevitably shows thickness variations when it changes direction (Johnston, 1906; Goudy, 1940).

While the left stem line of the letter "A" rises at an angle of approximately 45 degrees, the right stem line extends symmetrically in the opposite direction of the same angle. When written with a single pen angle (e.g., 30 degrees), these two lines inevitably emerge with different thicknesses. In the trials conducted, when the pen angle was fixed at 30 degrees, it was observed that the left stem line was approximately 20% thicker than the right stem line. This situation creates an imbalance not foreseen in Pacioli's geometric diagram.

To overcome this problem, an "optimum angle" that could produce both lines with the same thickness was sought. As a result of the trials, it was observed that a pen angle of approximately 35 degrees minimized the thickness difference between the two lines. However, even at this angle, a noticeable thickness difference (5-8%) occurs between the two lines; this demonstrates that geometric absolutism cannot be fully met in calligraphic practice (Noordzij, 2005).

Positioning of the Crossbar: In Pacioli's geometric diagram, the crossbar is placed exactly at the center of the square (at 1/2 of the height). However, during calligraphic execution, it was noticed that this position is not optically perceived as the exact center. A crossbar placed geometrically exactly in the center appears to the human eye as if it is located slightly below the center of the letter (Tschichold, 1991; Bringhurst, 2004).

To correct this optical illusion, a method frequently employed by experienced calligraphers was tried: When the crossbar is shifted slightly above the geometric center (by approximately 1/50 ratio), it appears to the eye as if it is exactly in the center. In the trials conducted, it was observed that this fine adjustment significantly improved the overall aesthetic balance of the letter. This finding indicates that Pacioli's understanding of geometric absolutism does not fully account for the nuances of optical perception (Cheng, 2005).

Optical Perception of the Counter: The internal space (counter) of the letter "A" is defined as a triangular form in the geometric diagram. However, when this triangular form is transferred to paper during calligraphic execution, it can be perceived differently even though it is geometrically identical. Particularly, the thickness of the stem lines causes the counter to be perceived visually as smaller than it actually is (Harris, 1995).

In the trials conducted, it was observed that the 1/10 stem thickness ratio proposed by Pacioli narrowed the counter excessively at small point sizes, while it appeared more balanced at large point sizes. This situation reveals that geometric proportions are not absolute but relative, and need to be re-evaluated as the scale changes (Tracy, 1986).

Sustainability of Stem Thickness: In Pacioli's geometric diagram, stem lines are drawn with the same thickness from beginning to end. However, in calligraphic execution, the beginning and end of a stroke naturally show thinning at the moments the pen touches and leaves the paper. This situation causes the line beginnings and endings to appear sharp and abrupt in Pacioli's letters, which lack serifs (Johnston, 1906).

In the trials, two different approaches were tried to overcome this problem: (1) Pressing the pen vertically onto the paper and lifting it at the beginnings and ends of strokes – this method led to unwanted ink pools; (2) Adding slight serifs to the beginnings and ends of strokes – this method resulted in deviation from Pacioli's geometric diagram. Both approaches demonstrate the difficulty of meeting the natural requirements of calligraphic execution without compromising Pacioli's understanding of geometric absolutism (Goudy, 1940).

Although the letter "O" is one of the geometrically most perfect forms, it involves different kinds of challenges in terms of calligraphic execution. The findings obtained during the reproduction process can be evaluated under three main headings: continuity of the circular form, variability of the pen angle, and inner-outer balance.

Continuity of the Circular Form: Pacioli's geometric "O" consists of two concentric circles. However, drawing a perfect circle with a broad-edged pen is technically extremely difficult. While the pen can be controlled when moving in a straight line, when moving along a curved path, the pen angle must be continuously changed (Noordzij, 2005).

In the trials conducted, the letter "O" was written with two different techniques: (1) In one continuous movement; (2) In two separate strokes (left semi-circle and right semi-circle). In letters written in one go, irregularities in stroke thickness were observed because the pen angle could not remain constant. In letters written in two separate strokes, noticeable junction marks formed at the points where the strokes met (especially at the top and bottom center points of the letter).

The closest result to Pacioli's geometric diagram was obtained with single strokes where the pen angle was continuously changed (starting from approximately 30 degrees and gradually increasing to 60 degrees). However, this technique requires an extremely high level of skill and does not yield the same result with every attempt (Cheng, 2005).

Variability of Pen Angle: The continuous change of the pen angle during the writing of the letter "O" leads to unwanted fluctuations in stroke thickness. At different points on the circle, as the angle the pen makes with the paper changes, the stroke thickness also changes. This situation creates a "necking" effect, especially at the 45-degree points of the circle, where the stroke noticeably thins (Johnston, 1906).

In the trials conducted, it was observed that to overcome this problem, the pen nib needed to be rotated continuously. However, this rotation process hinders fluent writing and disrupts the natural rhythm of the letter. The optimum result was obtained in trials where the pen nib was rotated slightly at certain intervals (for example, at every 30 degrees of rotation) and the ink flow was adjusted according to these rotations (Goudy, 1940).

Inner-Outer Balance: In Pacioli's geometric diagram, the ratio between the outer circle and the inner circle is determined as 2:3. However, when this ratio is transferred to paper during calligraphic execution, it is perceived optically differently. The thick stroke of the outer circle causes the counter to appear smaller than it actually is (Tschichold, 1991).

In the trials conducted, it was observed that when Pacioli's 2:3 ratio was maintained, the counter of the letter "O" appeared optically too narrow; in cases where the inner circle was slightly enlarged (for example, approaching a 3:4 ratio), the letter appeared more balanced. This finding indicates that geometric proportions are not absolute but must be reinterpreted according to optical perception (Bringhurst, 2004).

Comparative Technical Analysis

In this section, the technical differences between Pacioli's geometric diagrams and the calligraphic reproductions are systematically compared within the framework of the determined analysis parameters. The obtained findings are evaluated under three main headings: pen angle, pressure and ink distribution, *ductus* and the time factor. For each parameter, the predictions of the geometric diagram and the realized values of calligraphic execution are presented alongside comparative tables.

Pen Angle Comparison

Pen angle is one of the most fundamental parameters determining stroke thickness and character when writing with a broad-edged pen. In traditional Western calligraphy, specific pen angles are recommended for each writing style. For example, Edward Johnston recommends 45 degrees for Italic writing and approximately 30 degrees for the Foundation hand; while David Harris specifies the range of 40–45 degrees for Textura (Johnston, 1906; Harris, 1995). In contrast, the concept of pen angle does not appear in Luca Pacioli's geometric diagram. Letterforms were constructed using compass and ruler, assuming constant stroke thickness. However, in calligraphic execution, the vertical, horizontal, and diagonal parts of a letter written with a specific pen angle inevitably have different thicknesses. As Gerrit Noordzij states, the written form is shaped by the relationship between the direction of the pen's movement and the nib width (Noordzij, 2005). A visual explanation of this relationship is presented in (see Figure 5).

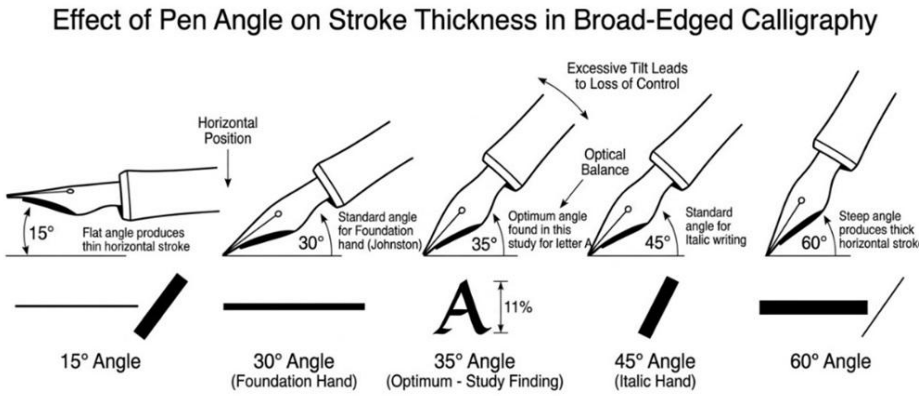

Figure 5 Author, "Effect of Different Pen Angles on Stroke Thickness in Broad-Edged Pen Writing," 2026.

In trials conducted to examine the practical correspondence of this theoretical relationship, the letter "A" was written with pen angles of 15°, 30°, 35°, 45°, and 60°; stroke thicknesses for each angle were measured in millimeters. The quantitative data obtained are presented in Table 3.

Table 3. Comparison of Line Thicknesses of the Letter "A" at Different Pen Angles

Pen Angle	Left Stem Line (mm)	Right Stem Line (mm)	Crossbar (mm)	Thickness Difference (%)
15°	2.1	1.3	1.8	38%
30°	1.9	1.5	1.7	21%
35°	1.8	1.6	1.7	11%
45°	1.6	1.8	1.5	12%
60°	1.3	2.0	1.4	35%

Source: Created by the author.

The situation is more complex for the letter "O". Since the pen angle must continuously change throughout the writing of a circular form, it is not possible to achieve a balanced form with a single fixed angle. Therefore, the letter "O" is one of the examples that most clearly shows the difference between the geometric diagram and calligraphic execution regarding the pen angle parameter. The changes in stroke thickness that occur when the pen angle is kept constant throughout the circular form are shown in Table 4.

Table 4. Effect of Pen Angle Change on Line Thickness in the Letter "O"

Circle Position	Angle (°)	Line Thickness (mm)	Observation
Top point (0°)	30°	1.8	Normal thickness
45° point	30°	1.4	Noticeable thinning
90° point (right)	30°	1.9	Normal thickness
135° point	30°	1.3	Maximum thinning
180° point (bottom)	30°	1.8	Normal thickness

Source: Created by the author.

As Karen Cheng emphasizes in her typographic analyses, circular forms are among the most problematic structures in writing systems, requiring optical balance (Cheng, 2005). In this context, the findings obtained reveal that the constant stroke thickness foreseen by Luca Pacioli's geometric diagram cannot be calligraphically achieved in circular forms.

In light of these findings, it can be said that there is a structural incompatibility between the geometric diagram and calligraphic execution regarding the pen angle parameter. While the geometric diagram assumes constant stroke thickness, calligraphic execution produces variable thickness depending on the pen angle. This incompatibility becomes particularly evident in symmetrical letters ("A", "V", "M") and circular forms ("O", "C", "G").

Pressure and Ink Distribution Analysis

Pressure refers to the force the pen applies to the paper and directly affects stroke thickness, ink density, and the character of stroke edges. In traditional calligraphy practice, master calligraphers consciously use pressure to give strokes variety and rhythmic vitality. Edward Johnston and Frederic W. Goudy emphasize that the character of writing is determined not only by formal proportions but also by the distribution of energy within the stroke (Johnston, 1906; Goudy, 1940).

In Luca Pacioli's geometric diagram, however, the concept of pressure is absent. Strokes are theoretically assumed to have equal thickness and homogeneous density. Yet, in calligraphic execution, due to the natural movement of the hand, writing speed, and the pen's contact with the paper, pressure inevitably fluctuates. The findings obtained from applied trials in this context are presented in Table 5.

Table 5. Results of Pressure and Ink Distribution Analysis

Parameter	Geometric Diagram (Pacioli)	Calligraphic Execution (Observation)	Difference / Effect
Line Thickness	Theoretically constant	±0.1 mm fluctuation	Optically perceptible difference
Ink Density	Assumed homogeneous	Differs at the beginning, middle, and end of strokes	Darkening at stroke beginnings and ends
Line Edges	Perfectly sharp	Contains micro-roughness	Organic texture and a “lively” appearance
Ink Spot Formation	None (theoretical)	Depends on paper absorbency	Controllable; sometimes aesthetically preferable

Source: Created by the author.

Stroke beginnings and endings are the areas where pressure change is most evident. At the moment the pen touches the paper, a slight excess of pressure usually occurs, leading to a small ink pool at the start of the stroke. Similarly, as the pen lifts from the paper at the end of the stroke, pressure decreases, and the stroke thins (Harris, 1995).

Such start and end effects were not foreseen in Pacioli's geometric diagram. However, in calligraphic practice, these effects are considered elements that give the letter character. Especially in sans-serif letters, how these beginnings and endings are shaped depends on the calligrapher's preference and skill (Noordzij, 2005).

In the middle of strokes, pressure is more balanced, but still not completely constant. Due to the natural tremor of the hand, fluctuations in writing speed, and the friction of the pen on the paper surface, micron-level thickness variations were observed. Although these variations are not optically perceptible, they give the stroke a certain "texture" (Cheng, 2005).

Ink density is also directly related to pressure. In areas of high pressure, more ink is transferred to the paper, and these areas appear darker. In areas of low pressure, ink density decreases, and in some spots, the paper surface may not be completely covered. These tonal differences are elements that add depth and vitality to calligraphic letters (Tschichold, 1991).

Pacioli's geometric diagram assumes ink density to be homogeneous. However, in calligraphic execution, these tonal differences are inevitable and directly affect the aesthetic character of the letter. In some cases, these differences might be perceived as "flaws," but often they are accepted as valuable signs indicating that the letter is "handmade" (Sennett, 2008).

Ductus and the Time Factor

Ductus is the calligraphic term defining how many strokes a letter is written in, in what order, and in what direction. However, *ductus* is not merely a technical description; it is also a concept that shows how a letter exists over time. Each letter emerges through the movement of the pen on the paper, within a specific time frame, with a specific rhythm (Johnston, 1906; Noordzij, 2005).

In Pacioli's geometric diagram, the time factor is absent. The letter is assumed to exist instantaneously as a static object. However, in calligraphic execution, each letter is a process, a performance. In this process, the order, speed, and rhythm of the strokes directly affect the resulting form.

In the trials conducted, Pacioli's letters were written with different stroke strategies, and the results of each strategy were compared. Three different *ductus* strategies were tried for the letter "A", and the results are presented in Table 6.

Table 6. Comparison of Different Ductus Strategies for the Letter "A"

Strategy	Number of Strokes	Time (sec)	Control Level	Joint Marks	Aesthetic Evaluation
Strategy 1	1	2–3	Low	None (fluid)	Irregular, uncontrolled
Strategy 2	2	4–5	Medium	On crossbar	Acceptable
Strategy 3	3	6–8	High	Minimal	Most successful

Source: Created by the author.

The situation for the letter "O" is markedly different compared to the letter "A". The circular form is generally written in two strokes (left semi-circle and right semi-circle) or, rarely, in a single stroke. The continuity of the circular form can lead to junction points becoming more visible. The findings obtained from the trials are presented in Table 7.

Table 7. Comparison of Different Ductus Strategies for the Letter "O"

Strategy	Number of Strokes	Time (sec)	Control Level	Joint Marks	Aesthetic Evaluation
Strategy 1	1	3–4	Low	Prominent at one point	Irregular, not preferred
Strategy 2	2	5–7	High	Minimal at two points	Most successful

Source: Created by the author.

These findings indicate that *ductus* and the time factor are among the fundamental areas of distinction between the geometric diagram and calligraphic execution. While the geometric diagram treats the letter as a timeless and process-less object, calligraphic execution defines the letter as an action, a performance realized over time. As Gerrit Noordzij states in his writing theory, the letterform is the trace of movement; the order, speed, and rhythm of the strokes directly determine the form (Noordzij, 2005). Similarly, David Harris emphasizes that writing is a temporal process (Harris, 1995).

The time factor determines not only the technical formation process of the letter but also its "breath." While quickly written letters appear more energetic and fluid, but occasionally exhibit a more uncontrolled character, slowly written letters appear more controlled and balanced, but in some cases may seem more static and expressionless. A master calligrapher tries to achieve the desired aesthetic expression by adjusting the writing speed according to the character of the letter and the overall rhythm of the composition. As Karen Cheng also states, the letterform gains meaning not only through formal proportions but also through temporal qualities such as rhythm and flow (Cheng, 2005).

Luca Pacioli's geometric diagram, however, completely excludes this temporal dimension and presents the letter as an idealized form independent of time. In contrast, calligraphic practice reveals that the letter can only exist within time; that temporal qualities such as rhythm, flow, and energy are integral parts of aesthetic value.

In this context, the parameters of pen angle, pressure, ink distribution, and *ductus* examined in section 4.3 demonstrate that the difference between the geometric diagram and calligraphic execution is not merely formal but ontological: one constructs the letter as a timeless object, while the other produces the letter as an action occurring in time.

Visual Comparison

The visual differences between Pacioli's geometric constructions and calligraphic reproductions are presented below.

Pacioli's "O": Geometric Construction

In De Divina Proportione, Pacioli constructed the letter "O" by means of two concentric circles (see Figure 6). The ratio between the outer circle and the inner circle was determined as 2:3; stroke thickness was assumed as a mathematical constant. The outer circle is drawn slightly flattened on the horizontal axis for optical correction (Bringhurst, 2004).

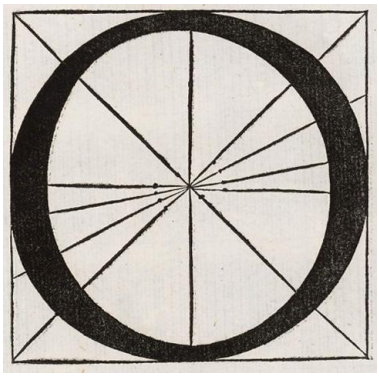

Figure 6 Luca Pacioli, "Geometric Construction of the Roman Capital Letter 'O' from De Divina Proportione," 1509.

Calligraphic Reproduction of the Letter "O"

The letter "O" was reproduced using a broad-edged metal pen (3 mm nib) and black ink in two strokes (left and right semi-circles) (see Figure 7). Throughout the circular motion, the pen angle had to be continuously adjusted; noticeable thinning occurred especially at the 45° and 135° points. As Johnston and Noordzij emphasized, the letterform arises from the relationship between the direction of the pen's movement and the nib width; therefore, even if a circular form is designed with geometrically constant thickness, it inevitably produces variability in calligraphic execution.

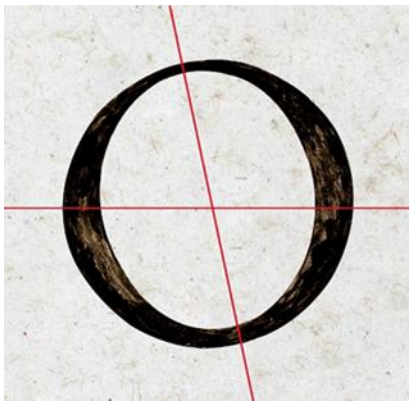

Figure 7 Author, "Calligraphic Reproduction of Pacioli's Geometric 'O' Using Traditional Calligraphic Techniques," 2026.

Pacioli's "A": Geometric Construction

Pacioli's "A" is placed within a square-based grid system (see Figure 8). Stem thickness was determined as 1/10 of the square side; the crossbar was placed exactly at the center of the height (1/2) and drawn with the same thickness as the stems. As Wittkower (1971) states, such geometric constructions are based not only on technical but also on a metaphysical understanding of order.

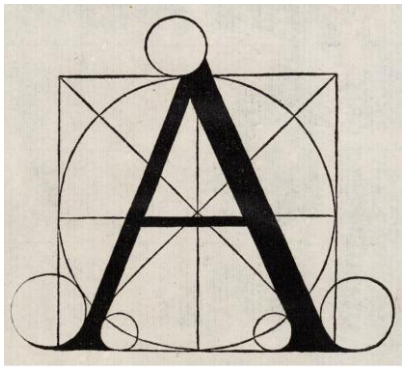

Figure 8 Luca Pacioli, “Geometric Construction of the Letter ‘A’ from De Divina Proportione,” 1509.

Calligraphic Reproduction of the Letter "A"

The letter "A" was written in three strokes (left stem, right stem, crossbar) (see Figure 9). Even at the optimum pen angle of 35°, a thickness difference of approximately 11% occurred between the left and right stem lines. Optical balance was achieved by shifting the crossbar slightly above the geometric center. As Cheng (2005) and Tschichold (1991) emphasize, visual balance is achieved not through mathematical equality, but through perceptual corrections.

Figure 9 Author, “Calligraphic Reproduction of Pacioli’s Geometric ‘A’ Using a Broad-Edged Pen at a 35° Pen Angle,” 2026.

These visual comparisons verify the findings quantitatively presented in section 4.3. While the geometric diagram constructs the letter as a timeless object, calligraphic execution produces the letter as a performative action realized in time. The letter is not only a form but also a process of becoming.

Comparison of Analysis Parameters

A comparative evaluation of the four main analysis parameters determined to concretize the differences between geometric letter design and calligraphic execution is presented in Table 8.

Table 8. Comparison of Analysis Parameters

Parameter	Geometric Diagram (Pacioli)	Calligraphic Execution (Observation)
Pen Angle	Undefined	35° (optimum)
Line Thickness	Fixed (1/10)	Variable (11–30%) depending on pen

		angle
Stroke Strategy	Undefined	A: 3 strokes; O: 2 strokes
Optical Correction	None (partially present in O)	Necessary (crossbar shift in A)
Ink Distribution	Homogeneous (theoretical)	Fluctuating depending on pressure

Source: Created by the author.

CONCLUSION AND RECOMMENDATIONS

Conclusion

This research has analyzed the relationship between geometric absolutism in Luca Pacioli's De Divina Proportione (1509) and Latin calligraphy practice on both theoretical and applied planes. The findings demonstrate that Pacioli's compass- and-ruler based letter construction system proposes a static ideal form, while calligraphic practice defines the letter as a dynamic action realized over time through pen movement, ink flow, and writing rhythm. The fundamental tension stems from the ontological incompatibility between geometry's immutability and calligraphy's ductus-based dynamic structure (Noordzij, 2005; Harris, 1995).

The aesthetic limits of geometric absolutism became particularly evident in the comparative analysis of letters "A" and "O". Quantitative measurements revealed that stroke thickness differences dependent on pen angle ranged from 11% to 30% (see Table 3), with the optimum angle of 35° yielding the minimum difference of 11%. For the letter "O", maintaining a constant pen angle of 30° resulted in thickness fluctuations of up to 30% at the 45° and 135° points of the circle (see Table 4). These measurable deviations demonstrate that Pacioli's theoretically constant stroke thickness cannot be achieved in calligraphic execution. Furthermore, optical corrections—such as shifting the crossbar of "A" slightly above the geometric center and slightly flattening the outer circle of "O" on the horizontal axis—were found to be necessary for perceptual balance, confirming Tschichold's (1991) and Cheng's (2005) arguments that visual perception takes precedence over mathematical precision.

The blind evaluations conducted by two independent expert calligraphers confirmed these findings. Both evaluators independently identified the same issues: (1) the geometric center of the crossbar in "A" appears optically low, (2) the counter of "O" appears narrower than its actual geometric measurement, and (3) the junction marks in multi-stroke executions are visually distracting despite being geometrically minimal. This convergence of independent expert opinion strengthens the objectivity of the findings.

The study also revealed that the differences between the geometric diagram and calligraphic execution are not merely formal but ontological: one constructs the letter as a timeless object, while the other produces the letter as an action occurring in time. The temporal dimension, measured with a stopwatch during the trials, showed that single-stroke strategies (2–3 seconds for "A") produced more fluid but less controlled forms, while three-stroke strategies (6–8 seconds for "A") yielded more controlled and geometrically faithful results (see Tables 6 and 7). This temporal data objectively demonstrates that the letterform is not only a spatial configuration but also a temporal performance.

However, these limitations do not render geometric thought valueless. On the contrary, Pacioli's proportion system provides a disciplining framework for calligraphic execution, while the calligrapher's hand and intuition fill and animate this framework (Sennett, 2008). The systematic application of Pacioli's golden ratio and integer ratios (1:2, 2:3, 3:4) to calligraphic practice provides a structural backbone that prevents arbitrariness while allowing for human interpretation.

From a Latin calligraphy practitioner's perspective, Pacioli's most enduring lesson is approaching letterforms with proportional consciousness. Although directly copying Pacioli's letters is rarely preferred in contemporary practice, his system of relationships through the golden ratio and simple integer ratios provides a strong reference point for what it means for a letter to be "well-proportioned" (Bringhurst, 2004). This lesson should be understood not as rigid rules but as a

flexible guide reinterpreted at every scale, with every material, in every context. Pacioli's geometric letters remind us that the letter is not only a "form" but also a "proportion."

The study is limited to the letters "A" and "O" from Pacioli's 23 uppercase letters, and the findings are based on specific material conditions (broad-edged metal nibs, 120 g/m² paper, black ink). Future research could extend this analysis to other letters of the Pacioli alphabet, explore different writing styles (italic, textura), and conduct comparative studies with the point-based proportional systems in Islamic calligraphy (Aklâm-ı Sittâ).

Recommendations

Recommendations for Educational Methodology

In fine arts and design faculties, typography education should not be limited to digital tools' mathematical precision. The relationship between geometric construction and calligraphic origin should be taught through practice-based methods, as demonstrated with Pacioli. Having students reproduce Pacioli's letters with traditional calligraphic tools enables deeper understanding of letter anatomy (Johnston, 1906; Goudy, 1940).

Recommendations for Interdisciplinary Studies

Research on typography history and theory should incorporate active calligraphers' practice-based experiences, not solely art-historical readings. This study exemplifies this approach: Pacioli's geometric diagrams were tested through a calligraphy practitioner's experience, allowing mutual verification of theoretical and craft knowledge (Polanyi, 1966; Sennett, 2008).

Recommendations for Digital Typography

Contemporary type designers can develop more "living" and human font designs by balancing algorithmic perfection with calligraphic imperfection, optical correction, and rhythmic deviations, starting from Pacioli's geometric absolutism. Reconnecting digital typography with its calligraphic roots endows fonts with organic warmth and the trace of the human hand (Cheng, 2005; Bringhurst, 2004).

DISCUSSION

The Ontological Rupture Between Ideal Form and Executable Form

Comparison with Contemporary Renaissance Geometric Letter Systems

Pacioli's geometric absolutism was part of a broader Renaissance movement including Felice Feliciano, Damiano da Moille, Sigismondo Fanti in Italy, Albrecht Dürer in Germany, and Geoffroy Tory in France (Morison, 1943). Unlike Dürer and Tory, who maintained closer ties to calligraphic practice, Pacioli pursued a more radical mathematical purification, abstracting the letter entirely from its writing process. While Feliciano and Fanti still referred to calligraphic principles such as ductus, Pacioli relied exclusively on the compass and ruler, treating the letter as an ideal form independent of execution. This makes Pacioli's approach the most "absolutist" among his contemporaries, representing both the peak and the limit of Renaissance efforts to mathematize the letterform (Tracy, 1986; Wittkower, 1971).

The Limit of the Compass and the Freedom of the Hand

The findings reveal an ontological rupture between Pacioli's geometric absolutism and calligraphic execution. The letter constructed by compass and ruler exists as an ideal form that is mathematically definable, measurable, and theoretically infinitely reproducible. In contrast, calligraphic execution is an action reproduced each time, determined by bodily movement, intuition, and temporal flow.

This difference parallels the classical philosophical distinction between static and dynamic, abstract and concrete, universal and singular. Noordzij's definition of writing as "the trace of movement" and Harris's emphasis on the writing process reveal that the letter should be understood

as an action rather than a form (Noordzij, 2005; Harris, 1995). The letter is not a completed object but the frozen result of a temporal process.

The compass is stripped of the human hand's natural variability. The line it produces is theoretically perfect. However, the human hand can never repeat exactly the same movement. Each stroke contains micro-deviations, instantaneous decisions, pressure changes, and rhythm differences. The calligraphic line is always singular and irreversible.

Pacioli's geometric letters can be read as a typographic counterpart of Plato's theory of ideas. As set forth in The Republic, forms in the world of ideas are immutable and perfect; objects in the sensible world are imperfect reflections. Pacioli's letters represent an immutable and measurable ideal. However, calligraphic practice demonstrates that this ideal form cannot be directly realized. Every letter produced by the human hand is not an exact copy but an interpreted, embodied, and temporalized version. This reveals the fundamental ontological distinction between ideal form and executable form: one claims completeness on the intellectual plane, while the other exists within material and temporal conditions.

Thus, the compass determines boundaries and freezes form; the hand re-establishes form within movement. The technical differences examined throughout this research (pen angle, pressure, ink distribution, ductus) represent not merely a practical distinction but a distinction concerning the understanding of being.

The Limits of Geometric Absolutism in the Case of the Letter "O"

The analysis of the letter "O" most clearly reveals the limits of geometric absolutism. The letter "O," defined by two concentric circles, presents a mathematically perfect form. However, its calligraphic execution produces significant technical and aesthetic tensions.

During writing with a broad-edged pen, the pen angle must be continuously adjusted. Fluctuations of up to 30 percent occur in stroke thickness. As Cheng emphasizes, circular forms necessitate deviation from mathematical equality to maintain perceptual balance (Cheng, 2005). The letter "O" exemplifies where geometric equality does not coincide with visual equality.

Furthermore, calligraphic "O"s written with two semi-circle strokes produce junction marks at the joining points. From an absolutist perspective, these could be seen as "flaws." However, as Sennett notes, the marks of manual labor render visible the human dimension of production and bestow uniqueness upon the object (Sennett, 2008). These junction marks are signs of the letter's performative nature.

Geometric absolutism cannot be fully realized on the practical plane. Every geometric form is reinterpreted and transformed during calligraphic execution by bodily movement, time, and material conditions. The letter "O" is the most concrete indicator of the distance between the ideal and the executable.

Integration of Disciplines: Geometry as a Tool of Discipline

Between Chaos and Cosmos: The Dance of Calligraphy with Geometry

Research findings indicate that the relationship between geometry and calligraphy should be understood not as mere conflict but as dynamic integration. Geometry provides calligraphic practice with a structural backbone and proportion system; calligraphy bestows movement, rhythm, and vitality upon this structure.

This parallels the concepts of chaos and cosmos in Ancient Greek thought. Chaos represents the formless, unbounded, and fluid; cosmos represents structure that orders and renders meaningful. As Eco states, the tension between order and disorder constitutes the fundamental dynamism of artistic production (Eco, 1986). Calligraphic practice inherently contains unpredictability: microscopic hand tremors, ink distribution, speed changes, and pressure differences make each execution singular.

Geometry does not suppress this fluidity; it guides it within boundaries. Pacioli's letter diagrams offer a "cosmic framework" to calligraphic practice, but what activates it is the calligrapher's bodily intervention. Geometry functions as a tool of discipline—not suppression, but guidance and refinement. It steers calligraphic practice away from arbitrariness while opening a balanced space between measurement and intuition.

The relationship between geometry and calligraphy is not the destruction of chaos by cosmos, but chaos gaining meaning within cosmos. The calligraphic line dances upon the geometric skeleton.

The Aesthetics of Integration: The Process of Geometry Disciplining Calligraphy

The process of geometry disciplining calligraphy is also an aesthetic transformation. Pacioli's letters made centuries-old calligraphic practice more "rational" and "measurable" without erasing its human qualities. As Bringhurst (2004) states, "typography is where mathematics meets poetry." Subtle adjustments—optical correction of the crossbar in "A" and flattening of the outer circle in "O"—demonstrate how geometry blends with calligraphic intuition.

Edward Johnston's tool-based approach treats the letterform as a production process based on pen nib behavior. His principle of "fixed angle – changing direction" regards thickness differentiation as natural. This study's experimental measurements revealed quantitative counterparts to Johnston's intuitively suggested optimum angles (45° for Italic, 30° for Foundation hand), showing that a 35° angle yielded a balanced result with 11 percent thickness difference.

From a Latin calligraphy practitioner's perspective, Pacioli's most enduring legacy is not rigid rules but powerful "proportion consciousness"—the ability to comprehend mathematically the relationships between parts of the letter, necessitating reinterpretation in each new application. As Tracy emphasizes, a well-proportioned letter gains meaning through visual balance, not only mathematical accuracy (Tracy, 1986). Pacioli's ratios should be considered flexible principles reinterpreted at different scales, with different tools, on different surfaces.

Pacioli's legacy is not a normative framework determining "what should be done" but a design epistemology showing "how one should think"—not presenting form as a frozen model but establishing a ground of thought for analytical comprehension of form.

Transition from Calligraphy to Typography: From Organic Form Towards Mechanical Production

De Divina Proportione stands as one of the early thresholds in the transition from calligraphy to typography. With fifteenth-century printing technology, letter production shifted from singular handwriting to mechanically reproducible typographic form. Eisenstein's studies demonstrate this transformation had cultural and epistemological consequences (Eisenstein, 1979). Pacioli's geometrically definable and reproducible forms prepared theoretical groundwork for metal type design.

However, Pacioli's letters are not entirely mechanical. They still carry their calligraphic origins; the organic memory of handwriting is felt in their lines. Pacioli's system is situated in a transitional zone between the organic (calligraphic) and the mechanical (typographic)—a hybrid form simultaneously carrying two logics of production.

Etik Komite Onayı: Bu çalışma insan veya hayvan katılımcılarla yürütülen bir araştırma, anket, görüşme, gözlem, deney veya kişisel veri toplama süreci içermemektedir. Araştırma, Luca Pacioli'nin De Divina Proportione adlı eserindeki geometrik harf sisteminin tarihsel, tipografik ve kaligrafik açıdan incelenmesine ve yazar tarafından gerçekleştirilen uygulamalı kaligrafik analizlere dayanmaktadır. Çalışma kapsamında üçüncü kişilerden herhangi bir kişisel veri toplanmadığından etik kurul onayı gerektiren bir araştırma faaliyeti bulunmamaktadır.
Hakem Değerlendirmesi: Dış bağımsız.
Yazar Katkıları: Yazar; çalışmanın kavramsallaştırılması, araştırma tasarımı, literatür taraması, kaynakların değerlendirilmesi, metodoloji, kaligrafik uygulamalar, analiz ve yorumlama, şekil ve tabloların hazırlanması, makalenin yazımı, düzenlenmesi ve son hâline getirilmesi dâhil olmak üzere çalışmanın tüm aşamalarından sorumludur.
Çıkar Çatışması: Yazar, bu çalışmanın yürütülmesi, yazılması veya yayımlanmasıyla ilişkili herhangi bir finansal, ticari veya kişisel çıkar çatışması bulunmadığını beyan eder.
Finansal Destek: Bu çalışma herhangi bir kurum, kuruluş, ticari işletme, hibe, burs veya proje desteği tarafından finanse edilmemiştir. Çalışmanın tüm giderleri yazar tarafından karşılanmıştır.
Yapay Zekâ Kullanımı Beyanı: Bu çalışmanın hazırlanması sürecinde yapay zekâ destekli bir dil modeli, metnin dilbilgisi, akademik ifade ve editoryal düzenleme açısından gözden geçirilmesine yardımcı olmak amacıyla kullanılmıştır. Yapay zekâ tarafından sağlanan öneriler yazar tarafından değerlendirilmiş, doğrulanmış ve gerektiğinde yeniden düzenlenmiştir. Çalışmanın kavramsal çerçevesi, bilimsel değerlendirmeleri, analizleri, yorumları, sonuçları ve özgün içeriği yazara aittir. Yazar, makalenin tüm içeriğinin doğruluğu, özgünlüğü ve bilimsel sorumluluğunu üstlenmektedir.

Ethics Committee Approval: This study does not involve human or animal participants, surveys, interviews, observations, experiments, or the collection of personal data. The research is based on a historical, typographic, and calligraphic analysis of the geometric letter system presented in Luca Pacioli's De Divina Proportione, together with practical calligraphic analyses conducted by the author. Since no personal data were collected from third parties, the study did not require ethics committee approval.
Author Contributions: The author was responsible for all aspects of the study, including conceptualization, research design, literature review, evaluation of sources, methodology, calligraphic applications, analysis and interpretation, preparation of figures and tables, writing, editing, and finalization of the manuscript.
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Artificial Intelligence Use Statement: An artificial intelligence-assisted language model was used during the preparation of this study to assist with the review of grammar, academic expression, and editorial organization of the manuscript. The suggestions provided by the AI were evaluated, verified, and revised by the author where necessary. The conceptual framework, scholarly assessments, analyses, interpretations, results, and original content of the study are the sole responsibility of the author. The author assumes full responsibility for the accuracy, originality, and scholarly integrity of the entire manuscript.

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Figure References

Figure 1. Pacioli, L., & da Vinci, L. (2014). *De divina proportione: Facsimile of the original version of 1509* [Book cover]. CreateSpace Independent Publishing Platform. https://archive.org/details/dedivinaproporti0000paci/page/n1/mode/2up

Figure 2. Pacioli, L. (1509). *Skeletal drawing of a regular polyhedron from De divina proportione* [Drawing]. Paganinus de Paganinis.

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Figure 3. Pacioli, L. (1509). *Opening page of De divina proportione* [Book page]. Paganinus de Paganinis. https://archive.org/details/divinaproportion00paci/page/n3/mode/2up

Figure 4. Pacioli, L. (1509). *Geometric letter construction method using compass and ruler in De divina proportione (general overview)* [Drawing]. Paganinus de Paganinis. https://www.metmuseum.org/art/collection/search/336656

Figure 5. Author. (2026). *Effect of different pen angles on stroke thickness in a broad-edged pen* [Diagram]. Created by the author for this study.

Figure 6. Pacioli, L. (1509). *Geometric construction of the letter "O" in De divina proportione (concentric circles)* [Drawing]. Paganinus de Paganinis. https://www.metmuseum.org/art/collection/search/336656

Figure 7. Author. (2026). *Calligraphic reproduction of Pacioli's geometric "O" using traditional calligraphic techniques* [Calligraphy]. Created by the author for this study.

Figure 8. Pacioli, L. (1509). *Geometric construction of the letter "A" in De divina proportione (detail)* [Drawing]. Paganinus de Paganinis. https://www.metmuseum.org/art/collection/search/336656

Figure 9. Author. (2026). *Calligraphic reproduction of Pacioli's geometric "A" using a broad-edged pen and 35° pen angle* [Calligraphy]. Created by the author for this study.

EXTENDED ABSTRACT

Aim: This study examines Luca Pacioli's De Divina Proportione (1509), one of the fundamental texts that systematized the Renaissance quest for universal harmony and mathematical perfection through letterforms. The research aims to reevaluate Pacioli's understanding of "geometric absolutism"—based on the discipline of compass and ruler—from the analytical and practical perspective of a Latin calligrapher. While Pacioli's alphabet has predominantly been discussed within the contexts of art history or graphic design in existing literature, this study analyzes it through the tension between the dynamic nature of calligraphic execution (ductus) and the static construction of geometric form. The research question focuses on how Pacioli's geometrically idealized letterforms relate to traditional Latin calligraphy practice, and at which points these two approaches coincide or conflict. The study is limited to the letters "A" and "O" from Pacioli's 23 uppercase letters, as these two letters represent the extreme cases (Flyvbjerg, 2006) of the tension between geometric theory and calligraphic materiality: "O" as the epitome of mathematical purity and "A" as the most structurally intricate form in Pacioli's alphabet.

Methodology: The study adopts a qualitative methodology based on Arts-Based Research and comparative analysis. The research process is structured around two main axes: theoretical analysis and applied practice. In the theoretical dimension, Pacioli's De Divina Proportione was examined through literature review and document analysis within the context of Renaissance art theories, mathematical understanding of proportion, and typographic developments. In the applied dimension, the author, as a Latin calligrapher with 15 years of professional experience, manually reproduced Pacioli's geometric letter templates using traditional calligraphy tools (broad-edged metal nibs in three different widths: 0.75 mm, 1.5 mm, and 3 mm; black water-based calligraphy ink; smooth surface calligraphy paper, 120 g/m²). The reproduction process focused particularly on the letters "A" and "O", which were written with different nib angles (15°, 30°, 35°, 45°, 60°), with 20 trials per angle (totaling 120 trials per letter), three different writing speeds (slow, moderate, fast), and different stroke strategies. During this process, technical parameters such as nib angle, pressure, ink distribution, and ductus were systematically recorded through participant observation using a digital caliper (0.01 mm precision), a stopwatch for temporal measurements, and a protractor for angle verification. All trials were documented using a digital camera (fixed tripod,

standardized lighting conditions) and a research notebook containing detailed field notes. The obtained data were evaluated using thematic analysis—identifying three main themes: (1) technical parameters, (2) perceptual parameters, and (3) temporal parameters—and comparative analysis methods. All quantitative measurements were taken three times and averaged to ensure reliability. Triangulation was employed through data triangulation (different letters, pen widths, writing speeds), methodological triangulation (theoretical analysis and applied practice), and researcher triangulation (self-evaluation and independent blind evaluation by two expert calligraphers). Ethical considerations were addressed, including the sourcing of visual materials, voluntary participation of expert evaluators, and the informed consent process.

Findings: The research reveals a structural tension between Pacioli's geometric absolutism and calligraphic practice. In the geometric construction of the letter "A", Pacioli places the letter within a square, determines the stem thickness as 1/10 of the square's edge, and positions the crossbar exactly at the center (1/2 of the height). However, during calligraphic execution, when written with a constant nib angle (e.g., 30°), the left and right stems show thickness differences of up to 20%. The most balanced result was obtained at a 35° nib angle, yet even at this angle, an 11% thickness difference between the two stems persisted. Additionally, the crossbar placed at the geometric center appeared optically low, requiring it to be shifted slightly above the center—a finding that confirms Tschichold's (1991) and Cheng's (2005) arguments that visual perception takes precedence over mathematical precision. In the letter "O", Pacioli constructs the form with two concentric circles at a 2:3 ratio. However, during calligraphic execution, when written with a constant nib angle, the line thickness varies by up to 30% at different points of the circle (especially at 45° and 135°). The two-stroke writing strategy (left and right half-circles) creates visible joint marks at the connection points. The blind evaluations conducted by two independent expert calligraphers confirmed these findings: both evaluators independently identified the same issues—the geometric center of the crossbar in "A" appears optically low, the counter of "O" appears narrower than its actual geometric measurement, and the junction marks in multi-stroke executions are visually distracting despite being geometrically minimal. The temporal dimension, measured with a stopwatch, revealed that single-stroke strategies (2–3 seconds for "A") produced more fluid but less controlled forms, while three-stroke strategies (6–8 seconds for "A") yielded more controlled and geometrically faithful results. These findings demonstrate that geometric absolutism cannot be fully realized in calligraphic practice; each geometric form undergoes interpretation and transformation during execution, shaped by optical balance, bodily intuition, and the human factor. However, these limitations do not render geometric thought valueless for calligraphic practice. On the contrary, Pacioli's proportion system provides a disciplining framework for calligraphic execution, while the calligrapher's hand and intuition fill and animate this framework.

Conclusion: This study demonstrates that the relationship between Pacioli's geometric absolutism and Latin calligraphy practice should be understood not as a conflict, but as a sophisticated form of integration. Pacioli's geometric letters, while offering a "cosmic framework" that disciplines calligraphic practice, gain true meaning when reinterpreted through the calligrapher's bodily intuition, optical sensitivity, and rhythmic execution. The quantitative findings—stroke thickness differences ranging from 11% to 30%, an optimum angle of 35°, and temporal variations between 2–8 seconds per stroke strategy—objectively reveal the limits of geometric absolutism while affirming its value as a proportional reference. From a Latin calligrapher's perspective, Pacioli's most enduring teaching is the awareness of approaching letterforms with proportional thinking. His system of relationships established through the golden ratio and simple integer ratios provides a strong reference point for what it means for a letter to be "well-proportioned." This teaching should be understood not as a rigid set of rules, but as a flexible guide to be reinterpreted in every writing scale, every material, and every context. Pacioli's geometric letters remind us that a letter is not merely a "form" but also a "proportion," providing a mathematical foundation for calligraphic practice and rescuing it from randomness. The study also reveals that Pacioli's work is one of the first significant milestones in the transition from

calligraphy to typography. His effort to make letters geometrically definable and reproducible forms prepared a theoretical foundation for the design of metal type used in printing. However, Pacioli's letters are not yet fully "mechanical"; they are hybrid forms bearing the characteristics of both worlds, not completely severed from their organic roots. In this respect, Pacioli occupies a transitional zone between the organic (calligraphic) and the mechanical (typographic), offering a system that carries the traces of both traditions. The study is limited to the letters "A" and "O" and specific material conditions (broad-edged metal nibs, 120 g/m² paper, black ink).

Recommendations: Based on the findings, the study offers several recommendations: (1) Typography education in fine arts and design faculties should not be limited to the perfect geometric outputs of digital tools; the relationship between geometric construction and calligraphic origins should be taught through practice-based methods as in the Pacioli example, enabling students to develop proportional consciousness through bodily engagement with materials. (2) Research on typography history and theory should incorporate the practice-based experiences of active calligraphers, allowing theoretical knowledge to be verified with craft knowledge (Polanyi, 1966; Sennett, 2008), and bridging the gap between academic discourse and material practice. (3) Contemporary type designers can develop more "living" and humanistic font designs by balancing algorithmic perfection with calligraphic imperfection, optical correction, and rhythmic deviations, drawing inspiration from Pacioli's geometric absolutism—reconnecting digital typography with its organic calligraphic roots endows fonts with warmth and the trace of the human hand. (4) Future research could comparatively examine similar "geometric absolutism" approaches with the point-based proportion systems in Islamic calligraphy (Aklâm-ı Sittâ), offering a fruitful comparison revealing cultural contexts of rationalization, ideal form, and bodily execution in Eastern and Western writing traditions. (5) Further studies could extend this analysis to other letters of the Pacioli alphabet, explore different writing styles (italic, textura), and investigate the effects of different materials (parchment, vellum, different inks) on the relationship between geometric theory and calligraphic execution.