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A multi-level futures analysis of European teleophthalmology through 2040: development and application of a conceptual framework for healthcare transformation

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Abstract

As Europe faces unprecedented demographic shifts and technological advancement, the future of eye care delivery stands at a critical juncture. This paper develops a comprehensive conceptual framework for understanding how teleophthalmology will transform European healthcare delivery through 2040. Drawing on futures studies methodology and healthcare innovation theory, we propose a multi-level framework that captures the dynamic interplay between technological innovation, social systems, and healthcare delivery models. The framework examines transformation across macro (landscape), meso (regime), and micro (niche) levels while incorporating temporal dimensions that reflect the evolutionary nature of healthcare innovation. Through analysis of current trends and emerging developments, we present three detailed scenarios for the future of European teleophthalmology: fully integrated digital eye care, hybrid model with regional variations, and technology-enabled traditional care. These scenarios explore how different combinations of technological capability, social acceptance, and institutional readiness might shape the evolution of eye care delivery. Our analysis reveals critical challenges and opportunities in implementing teleophthalmology across diverse European healthcare systems, including issues of healthcare equity, data governance, professional adaptation, and cross-border care delivery. The paper contributes to both theoretical understanding of healthcare futures and practical implementation of digital health solutions while considering the unique characteristics of European healthcare systems. The framework and scenarios presented provide valuable guidance for policymakers, healthcare providers, and technology developers in shaping the future of eye care delivery across Europe.

Keywords Teleophthalmology, Healthcare futures, European healthcare systems, Digital health transformation

Introduction

The landscape of European healthcare is undergoing a profound transformation, driven by unprecedented demographic shifts, technological advances, and evolving patient needs. As Europe faces an increasingly aging population, with projections indicating that 28.5% of the EU population will be aged 65 or older by 2100 compared to 20.3% in 2019 [11], the demand for eye care services is expected to surge dramatically. This demographic transition presents both challenges and opportunities for healthcare systems across Europe, particularly in the domain of ophthalmology, where age-related eye

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conditions such as cataracts, glaucoma, and macular degeneration require consistent monitoring and intervention.

The current state of European eye care delivery reveals significant disparities in access and quality of care. Geographic variations in the distribution of eye care professionals, particularly between urban and rural areas, have created substantial inequities in service delivery. Research by the European Forum Against Blindness (2019) indicates that nearly 70% of ophthalmologists are concentrated in urban centers, leaving rural populations underserved. This maldistribution of healthcare resources is further complicated by the increasing prevalence of chronic eye conditions that require regular monitoring and intervention. The World Health Organization's World Report on Vision ([60]) highlights that at least 2.2 billion people globally have vision impairment, with a significant portion residing in European nations where healthcare systems struggle to meet the growing demand for eye care services.

The emergence of teleophthalmology represents a potential paradigm shift in how eye care services can be delivered across European healthcare systems. This technological evolution arrives at a crucial moment when traditional healthcare delivery models are being challenged by resource constraints and increasing patient expectations for accessible, efficient care. However, the future implementation and integration of teleophthalmology within European healthcare systems require careful consideration of multiple interconnected factors that extend beyond mere technological capability.

The concept of futures thinking in healthcare transformation is particularly relevant when considering the implementation of teleophthalmology across Europe. As Swan [50] argues in the Journal of Futures Studies, healthcare futures must be examined through multiple lenses, including technological, social, and cultural perspectives, to create sustainable and equitable solutions. This multi-faceted approach becomes even more critical in the European context, where healthcare systems must operate within diverse national policies while striving for cross-border integration and standardization.

Understanding the future trajectory of teleophthalmology in Europe requires a comprehensive framework that considers not only technological advancement but also social implications, regulatory frameworks, and healthcare system readiness. The European Union's Digital Health Strategy (European [12, 13]) emphasizes the importance of digital transformation in healthcare, yet the specific pathways for implementing teleophthalmology remain unclear and vary significantly across member states. This variation creates both challenges and opportunities for developing a unified approach to digital eye care delivery while respecting national healthcare system autonomy.

Recent developments in artificial intelligence and digital health technologies have accelerated the potential for teleophthalmology to address current healthcare challenges. Studies by Kern et al. [28] in the European Journal of Ophthalmology demonstrate that AI-enabled screening tools can achieve diagnostic accuracy comparable to human specialists in certain conditions, suggesting a promising future for automated eye care services. However, the integration of these technologies into existing healthcare systems requires careful consideration of ethical implications, professional adaptation, and patient acceptance.

The purpose of this paper is to develop a conceptual framework for understanding how teleophthalmology will reshape European healthcare delivery models over the next two decades. This framework aims to bridge the gap between current technological capabilities and future healthcare needs while considering the unique characteristics of European healthcare systems. By examining potential futures through multiple scenarios, this research contributes to both the theoretical understanding of healthcare transformation and the practical implementation of teleophthalmology across Europe.

Our approach draws upon futures studies methodology to examine the complex interplay between technological innovation, social dynamics, and healthcare system evolution. As emphasized by Bell [3] in his seminal work on futures studies, understanding potential futures requires systematic examination of current trends, emerging issues, and critical uncertainties. This paper applies these principles specifically to the domain of eye care, considering how teleophthalmology might evolve within the unique context of European healthcare systems.

The significance of this research extends beyond the immediate domain of ophthalmology, offering insights into how digital health technologies can be effectively integrated into healthcare systems while maintaining equity, quality, and accessibility. As European healthcare systems grapple with the challenges of an aging population and increasing chronic disease burden, the frameworks and scenarios developed in this paper provide valuable guidance for policymakers, healthcare providers, and technology developers in shaping the future of healthcare delivery.

Theoretical foundation and literature review section

The theoretical underpinning of futures research in healthcare transformation, particularly in the context of teleophthalmology, requires a multifaceted examination of both futures studies methodology and healthcare

innovation theories. This section explores the theoretical foundations that inform our understanding of how technological innovations in healthcare are shaped, adopted, and transformed within societal contexts.

Futures studies methodology in healthcare

The application of futures studies methodology to healthcare transformation has evolved significantly over the past decades. Dator's [9] foundational work on alternative futures provides a crucial framework for understanding how healthcare systems might evolve, identifying four generic alternative futures: continuation, collapse, disciplined society, and transformation. These alternatives, when applied to healthcare innovation, help us understand potential trajectories for teleophthalmology adoption and implementation. Building on this foundation, Inayatullah's [27] Causal Layered Analysis (CLA) methodology offers a deeper analytical framework for understanding the multiple levels at which healthcare transformation occurs, from the visible surface of technological implementation to the deeper cultural and mythological underpinnings that shape how societies view and interact with healthcare technologies.

The integration of futures thinking into healthcare planning has been further developed through the work of Miller [36] in"Transforming the Future: Anticipation in the 21 st Century,"which emphasizes the importance of anticipatory systems in healthcare planning. This approach is particularly relevant for teleophthalmology, where anticipating future needs and challenges is crucial for successful implementation. The European Commission's Foresight Network has also contributed significantly to this field, developing methodologies specifically tailored to European healthcare contexts and challenges.

Technological determinism versus social shaping of technology

The debate between technological determinism and social shaping of technology is particularly relevant to understanding the future of teleophthalmology in Europe. While technological determinism suggests that technological advancement drives social and organizational change, scholars like Williams and Edge [58] argue for a more nuanced understanding through the social shaping of technology (SST) perspective. Their work demonstrates how technological innovations in healthcare are shaped by social, institutional, and cultural factors rather than following a predetermined path.

MacKenzie and Wajcman's [33] seminal work on the social shaping of technology provides crucial insights into how teleophthalmology solutions might be adapted and transformed within different European healthcare contexts. Their framework helps explain why identical technological solutions often yield different outcomes across various healthcare systems, emphasizing the importance of social and organizational contexts in technological implementation.

Theory of disruptive innovation in healthcare

Christensen's theory of disruptive innovation, when applied to healthcare, offers valuable insights into how teleophthalmology might transform traditional eye care delivery models. However, as Hwang and Christensen [26] note in their analysis of healthcare innovation, healthcare presents unique challenges for disruptive innovation due to complex regulatory environments and professional structures. Their work is particularly relevant for understanding how teleophthalmology might navigate these challenges within European healthcare systems.

The study by Yu and Hang [61] extends this theoretical framework by examining how regulatory environments influence the path of disruptive innovations in healthcare. Their findings suggest that successful healthcare innovations must balance disruptive potential with institutional constraints, a particularly relevant consideration for teleophthalmology implementation across diverse European healthcare systems.

European healthcare integration theories

The theoretical foundation for understanding healthcare integration in Europe draws heavily from neo-functionalist and inter-governmentalist theories of European integration. Hervey's [24] analysis of European healthcare policy integration provides a crucial framework for understanding how technological innovations like teleophthalmology might be integrated across European healthcare systems. His work emphasizes the importance of understanding both formal and informal mechanisms of policy diffusion and implementation.

The concept of"Europeanisation"in healthcare, as developed by Vollaard et al. [54], offers additional insights into how national healthcare systems adapt to European-level innovations and policies. Their work is particularly relevant for understanding how teleophthalmology solutions might be standardized across European healthcare systems while maintaining necessary flexibility for national and regional adaptation.

Current frameworks for analyzing healthcare futures have evolved significantly from traditional forecasting methods. The work of Schiavone and Ferretti [46] in developing comprehensive healthcare futures frameworks emphasizes the importance of considering multiple stakeholder perspectives and system levels. Their"Healthcare 2040"framework provides

valuable insights into how technological innovations might reshape healthcare delivery models.

The"Multi-Level Perspective"(MLP) framework, as developed by Geels [18], offers a particularly useful approach for understanding how technological innovations transition from niche applications to system-wide implementation. This framework helps explain how teleophthalmology might move from isolated pilot projects to widespread adoption across European healthcare systems.

Integration of theoretical perspectives

The integration of these various theoretical perspectives provides a robust foundation for understanding the future of teleophthalmology in Europe. Drawing on futures studies methodology, social shaping of technology, disruptive innovation theory, and European integration theories, we can better understand the complex interplay of factors that will influence teleophthalmology's development and implementation.

This theoretical foundation suggests that successful implementation of teleophthalmology will require careful consideration of both technological capabilities and social contexts. As Grin et al. [23] argue in their work on transitions towards sustainable futures, technological innovations must be understood within broader societal transformation processes. This perspective is particularly relevant for teleophthalmology, where success depends not only on technological advancement but also on social acceptance, professional adaptation, and system integration.

Conceptual framework

The transformation of European eye care through teleophthalmology represents a complex socio-technical transition that requires a comprehensive conceptual framework to understand its multiple dimensions and potential trajectories. Building upon the theoretical foundations discussed in the previous section, we propose a multi-level framework that captures the dynamic interplay between technological innovation, social systems, and healthcare delivery models in shaping the future of European eye care (see Fig. 1).

Multi-level framework overview

Our proposed framework synthesizes elements from the Multi-Level Perspective (MLP) developed by Geels and Schot [19] with healthcare-specific considerations drawn from the work of Greenhalgh et al. [21] on technology adoption in health services. The framework conceptualizes teleophthalmology transformation across three interconnected levels: macro (landscape), meso (regime), and micro (niche) levels, while incorporating temporal dimensions that reflect the evolutionary nature of healthcare innovation.

At the macro level, our framework addresses broad societal trends and pressures that shape the context for teleophthalmology adoption. These include demographic shifts documented by Eurostat (2021), changing patient expectations described by Kraus et al. [30] in their analysis of European healthcare preferences, and technological advancement trajectories outlined in the European Commission's Digital Health Strategy ([15]). The macro level also encompasses regulatory frameworks and policy environments that enable or constrain teleophthalmology implementation. This level represents the broader context within which healthcare transformation occurs, including factors such as aging populations, urbanization trends, and evolving healthcare policies at the European level.

The meso level focuses on existing healthcare system structures and institutional arrangements. This includes professional networks, established clinical practices, and organizational routines that must adapt to accommodate teleophthalmology solutions. Drawing on the work of May et al. [34] on implementation science in healthcare, our framework specifically addresses how existing healthcare delivery models can evolve to incorporate digital eye care services while maintaining quality and continuity of care. The meso level is particularly crucial in the European context, where healthcare systems must balance national sovereignty with cross-border integration and standardization.

At the micro level, the framework examines specific teleophthalmology innovations and their interactions with individual stakeholders. This includes consideration of provider-patient relationships, clinical workflows, and local adaptation processes. The work of Shaw et al. [48] on digital health implementation provides valuable insights into how micro-level interactions influence the success or failure of healthcare innovations. This level is essential for understanding how teleophthalmology solutions are actually implemented and used in practice, considering factors such as user acceptance, training needs, and local cultural contexts.

Temporal dimensions and integration points

The framework incorporates three temporal horizons that span across all levels: immediate (0–5 years), medium-term (5–10 years), and long-term (10–20 years). This temporal structure aligns with the futures studies methodology proposed by Voros [55] and allows for the examination of how different aspects of teleophthalmology implementation might evolve over time. Each temporal horizon is characterized by distinct challenges and

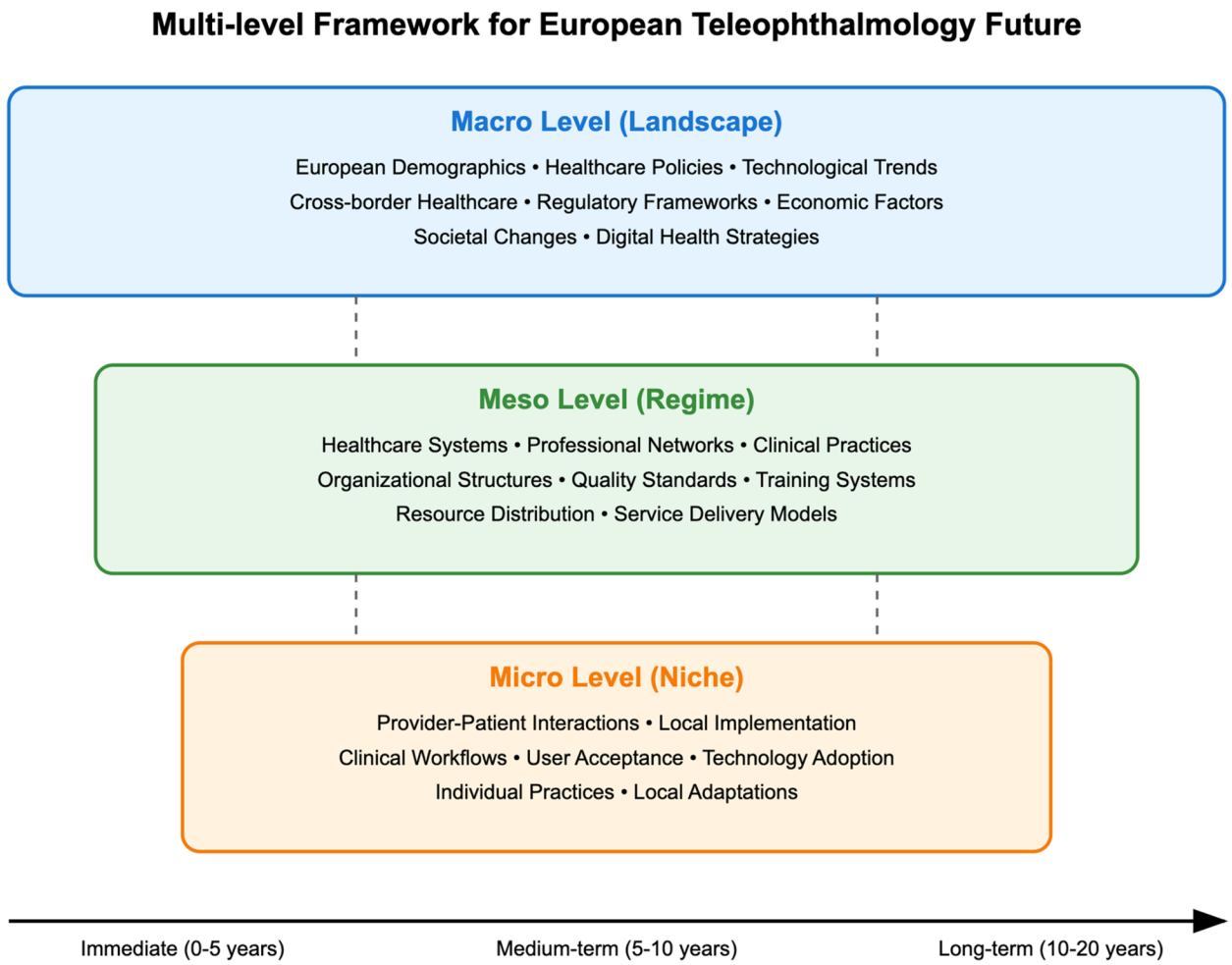

Fig. 1 Multi-level framework for European teleophthalmology future

opportunities, reflecting the progressive maturation of both technology and social systems.

The immediate horizon focuses on current implementation challenges and early adoption patterns, where existing technologies are being integrated into current healthcare practices. The medium-term horizon addresses the evolution of healthcare delivery models and the emergence of new technological capabilities. The long-term horizon explores potential transformative changes in how eye care is conceptualized and delivered across Europe.

Integration points within the framework represent critical junctures where different levels interact and influence each other. These integration points are particularly important for understanding how teleophthalmology solutions can be effectively implemented across diverse European healthcare systems. The work of Kierkegaard [29] on cross-border healthcare in Europe provides valuable insights into how these integration points function within the European context. These integration points serve as channels through which innovations, practices, and policies flow between levels, facilitating system-wide transformation.

Key drivers of change

Our framework identifies four primary drivers of change that operate across all levels: technological innovation, social acceptance, professional adaptation, and system integration. These drivers, identified through synthesis of existing literature on healthcare transformation [31] and digital health adoption [22], interact dynamically to shape the evolution of teleophthalmology services.

Technological innovation serves as a fundamental driver, encompassing advances in diagnostic capabilities, artificial intelligence, and communication technologies. Social acceptance reflects the willingness of patients, healthcare providers, and other stakeholders to embrace new models of care delivery. Professional adaptation addresses how healthcare providers and organizations modify their practices and structures to accommodate

teleophthalmology solutions. System integration represents the processes through which teleophthalmology becomes embedded within existing healthcare systems and practices.

Framework application and implications

The application of this framework reveals several key insights for the future of teleophthalmology in Europe. First, the success of teleophthalmology implementations depends on alignment across all three levels of the framework. As demonstrated by Greenhalgh et al. [22] in their study of digital health adoption, misalignment between levels can lead to implementation failure even when individual components are well-designed.

Second, the framework highlights the importance of temporal considerations in planning teleophthalmology implementations. Different aspects of the system evolve at different rates, requiring careful orchestration of change processes. This aligns with the findings of May et al. [34] regarding the importance of implementation timing in healthcare innovation.

Finally, the framework emphasizes the role of integration points in facilitating successful teleophthalmology adoption. These points serve as critical interfaces where different system elements must align for successful implementation, as highlighted by Shaw et al. [48] in their analysis of digital health integration.

Framework development methodology

The development of our multi-level framework emerged from a rigorous six-month research process conducted between January and June 2024, employing mixed methods to ensure both theoretical depth and empirical grounding. Our approach integrated systematic literature analysis with extensive qualitative interviews, combining deductive framework development with inductive insights from stakeholder engagement.

Our research began with a comprehensive systematic review following PRISMA guidelines to map the theoretical landscape of teleophthalmology futures. We searched Web of Science, Scopus, and PubMed databases using combinations of terms including"teleophthalmology," "digital eye care,""healthcare futures,""socio-technical transitions,"and"European healthcare innovation."This initial search yielded 487 articles, which we screened using predetermined inclusion criteria focusing on relevance to European healthcare contexts, futures methodologies, and digital health transformation. Through this rigorous screening process, we identified 142 core articles for detailed analysis. The first author conducted the primary theoretical synthesis, systematically mapping existing frameworks from futures studies and healthcare innovation literature, while the second author focused on extracting empirical insights about European healthcare system variations and implementation challenges.

The Multi-Level Perspective framework by Geels and Schot [19] emerged as our theoretical foundation due to its demonstrated effectiveness in analyzing socio-technical transitions. However, recognizing that healthcare transformation requires domain-specific considerations, we adapted this framework by integrating elements from Greenhalgh et al.'s [21] NASSS framework for healthcare technology adoption and insights from European healthcare integration theory. This adaptation process involved iterative refinement through multiple rounds of conceptual mapping, where we identified points of convergence and divergence between generic transition frameworks and healthcare-specific requirements.

To ensure our framework reflected practical realities rather than purely theoretical constructs, we conducted extensive empirical research across six European countries selected to represent diverse healthcare systems and digital maturity levels: Germany and Sweden representing advanced digital health adoption, France and Spain representing large centralized systems with varying digital integration, and Poland and Bulgaria representing emerging digital health markets. Between March and April 2024, we conducted 28 semi-structured interviews (Ethics approval was obtained from the Human Subjects Review Committee of the American University in Bulgaria with the identification number of ELG-011024) with stakeholders strategically selected to provide comprehensive perspectives on teleophthalmology futures. Our interview sample included eight practicing ophthalmologists with direct teleophthalmology experience, six healthcare policymakers working at both national and EU levels, five technology developers specializing in ophthalmic solutions, four patient organization representatives, and five healthcare system administrators responsible for digital transformation initiatives.

Each interview (conducted online), lasting between 30 to 40 min, followed a semi-structured protocol that explored participants' experiences with current teleophthalmology implementations, perceived barriers and enablers, future expectations, and critical factors for successful transformation. The first author conducted interviews in Northern and Western European countries, while the second author covered Southern and Eastern European contexts, ensuring linguistic and cultural appropriateness. All interviews were recorded and transcribed verbatim. We then undertook a targeted thematic review, drawing on Braun and Clarke's [5] principles to identify recurring concepts and patterns most relevant to teleophthalmology futures. This was a pragmatic, fit-for-purpose process aimed at informing the framework's structure rather than producing a standalone qualitative

dataset. Themes were compared between authors, and any differences in interpretation were resolved through discussion. This process highlighted fifteen critical dimensions, spanning technological infrastructure, professional adaptation, regulatory harmonization, and patient empowerment, that consistently emerged across stakeholder groups.

The scenario development phase employed structured futures methodologies to translate our framework into concrete alternative futures. In April 2024, we organized an intensive one-day online scenario planning workshop in. The workshop brought together twelve participants, including ourselves and ten invited experts representing ophthalmology practice, digital health innovation, health economics, patient advocacy, and European health policy. We employed the morphological analysis technique combined with the two-by-two scenario matrix approach, identifying degree of technological integration and implementation approach as the two critical uncertainties with highest impact and greatest uncertainty.

Through facilitated exercises including environmental scanning, cross-impact analysis, and narrative development, participants collaboratively constructed initial scenario frameworks. The first part of the workshop focused on identifying driving forces, predetermined elements, and critical uncertainties, while the second part concentrated on developing internally consistent scenario narratives. Following the workshop, we spent two weeks refining these scenarios, with the first author ensuring theoretical consistency with the multi-level framework while the second author validated scenarios against current European healthcare policies, regulations, and institutional arrangements. We particularly focused on ensuring each scenario represented a plausible and internally consistent future rather than simple extrapolations of current trends.

To validate our framework and scenarios, we implemented a modified Delphi process between May and June 2024. We recruited ten additional experts who had not participated in earlier phases. The Delphi process consisted of two rounds of structured feedback, with experts rating framework completeness, scenario plausibility, and strategic implications on five-point Likert scales while providing qualitative comments for improvement. The first Delphi round achieved 73% consensus on framework structure but revealed concerns about temporal dimensions and cross-border implications. We incorporated this feedback through substantial revisions, particularly strengthening our analysis of implementation timelines and European integration challenges. The second round achieved 91% consensus, with statistical analysis showing high inter-rater reliability (Cronbach's $\alpha = 0.87$) for framework completeness and scenario coherence. The qualitative feedback from the Delphi process enriched our understanding of implementation nuances and helped identify strategic implications we had initially overlooked.

Framework applications and scenarios

The proposed conceptual framework enables a structured exploration of potential futures for European teleophthalmology through the development and analysis of distinct scenarios. These scenarios, grounded in current trends and emerging developments, represent different possible trajectories for the evolution of eye care delivery across Europe. Drawing upon the scenario planning methodology outlined by van der Heijden [53] and the healthcare futures work of Börjeson et al. [6], we present three comprehensive scenarios that explore how teleophthalmology might transform European eye care by 2040.

Scenario A: fully integrated digital eye care

The first scenario envisions a future where teleophthalmology has become fully integrated into European healthcare systems, fundamentally transforming how eye care is delivered. This transformation aligns with the broader digitalization of healthcare services described by Topol [52] in"Deep Medicine"and builds upon current European Union initiatives in digital health integration. In this scenario, artificial intelligence-enabled screening and diagnostic tools, as documented by Ting et al. [51] in their comprehensive review of AI applications in ophthalmology, have become standard components of primary eye care delivery.

The integration of teleophthalmology in this scenario extends beyond simple remote consultations to encompass a comprehensive digital eye care ecosystem. Drawing from the work of Benet and Pellicer-Valero [4] on AI-enabled eye care delivery, this scenario features automated screening programs integrated with primary care services, AI-assisted diagnosis and treatment planning, and continuous remote monitoring of chronic eye conditions. The European Union's cross-border healthcare directive has evolved to specifically address digital health services, facilitating seamless eye care delivery across member states.

Professional roles have adapted significantly in this scenario, with ophthalmologists focusing primarily on complex cases and surgical interventions while AI systems and trained technicians handle routine screening and monitoring. This transformation of professional roles aligns with the predictions made by Obermeyer and Emanuel [41] regarding the evolution of medical specialties in response to AI integration. The scenario also encompasses significant changes in healthcare education and training, with new specializations emerging

at the intersection of ophthalmology and digital health technology.

Scenario B: hybrid model with regional variations

The second scenario presents a more nuanced future where teleophthalmology adoption and implementation vary significantly across European regions, reflecting different healthcare system structures, resource availability, and cultural preferences. This scenario builds upon the work of Greenhalgh et al. [22] on technology adoption in healthcare settings and recognizes the persistent influence of regional healthcare traditions and institutional arrangements.

In this hybrid model, some regions have achieved high levels of teleophthalmology integration, while others maintain more traditional service delivery models enhanced by selective digital tools. This variation is consistent with current patterns of healthcare innovation adoption across Europe, as documented by Ricciardi et al. [44] in their analysis of digital health transformation in the European Union. The scenario recognizes that different regions face distinct challenges and opportunities in implementing teleophthalmology solutions.

Cross-border collaboration plays a crucial role in this scenario, with more digitally advanced regions supporting the gradual transformation of healthcare delivery in other areas. This approach builds upon existing European initiatives in healthcare cooperation, as described by Brigitta [7] in their analysis of cross-border healthcare collaboration. The scenario envisions the emergence of regional centers of excellence that combine advanced teleophthalmology capabilities with traditional eye care services, serving as nodes in a distributed European eye care network.

Scenario C: technology-enabled traditional care

The third scenario describes a future where technological advancement enhances rather than transforms traditional eye care delivery models. This scenario aligns with the socio-technical systems perspective outlined by Geels and Schot [20] and recognizes the resilience of established healthcare practices and professional identities. In this future, teleophthalmology tools augment existing care delivery models without fundamentally altering the traditional doctor-patient relationship.

Drawing from the work of May et al. [34] on healthcare innovation implementation, this scenario emphasizes the importance of maintaining continuity in care delivery while incrementally incorporating new technological capabilities. Teleophthalmology tools are primarily used to enhance efficiency and accessibility within traditional care settings, rather than replacing existing service delivery models. This approach addresses concerns about the preservation of clinical expertise and professional autonomy raised by Panch et al. [42] in their analysis of AI integration in medical practice.

To provide an accessible visual synthesis of the three scenarios, Fig. 2 presents a comparative overview of the key characteristics and pathways for European teleophthalmology through 2040. Each panel captures the essence of its respective scenario through distinctive visual elements and quantified metrics. The figure emphasizes the progression from complete digital transformation requiring substantial investment and training (Scenario A), through flexible regional adaptation with moderate resource requirements (Scenario B), to incremental enhancement of existing care models with minimal disruption (Scenario C). The visual design employs different color schemes and icons to reflect the

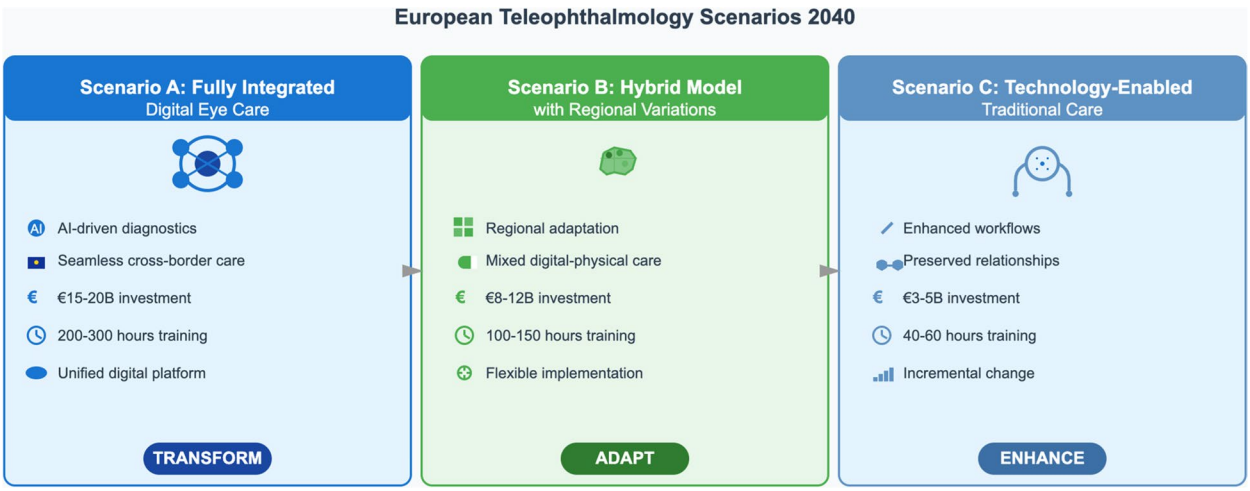

Fig. 2 Visual summary of three European teleophthalmology scenarios 2040

fundamental nature of each scenario: networked AI systems for full integration, a differentiated map for regional variation, and a digitally-enhanced traditional medical symbol for technology-enabled care.

To facilitate systematic comparison and strategic planning, Table 1 presents a comprehensive comparative analysis of the three teleophthalmology scenarios across fifteen critical dimensions. These dimensions span technological, organizational, economic, and social aspects of healthcare transformation, providing stakeholders with a structured framework for understanding the distinct characteristics and implications of each potential future. The table synthesizes the narrative scenario descriptions into measurable and comparable elements, including quantitative estimates for investment requirements, training needs, and market opportunities where applicable. This comparative framework enables stakeholders to identify key decision points, resource requirements, and strategic priorities associated with different evolutionary pathways of teleophthalmology implementation in Europe.

Table 1 Comparative analysis of European teleophthalmology scenarios 2040

Dimension	Scenario A: Fully Integrated Digital Eye Care	Scenario B: Hybrid Model with Regional Variations	Scenario C: Technology-Enabled Traditional Care
Technology Integration Level	Complete digital transformation with AI-driven diagnostics and treatment planning	Selective integration varying by region; mixed digital-traditional approaches	Technology as enhancement tool; maintains traditional care structures
Geographic Coverage	Uniform implementation across all EU member states with standardized protocols	Heterogeneous adoption with digital leaders and traditional followers	Localized implementation based on institutional preferences
Professional Roles	Fundamental restructuring: ophthalmologists focus on complex cases; AI handles routine care	Varied role adaptation depending on regional digital maturity	Minimal role change; technology supports existing professional structures
Patient Journey	Fully digital pathway from screening to follow-up; minimal physical consultations	Mixed pathways combining digital and in-person care based on regional capabilities	Traditional pathways enhanced by digital tools at specific touchpoints
Cross-border Care	Seamless cross-border services enabled by standardized digital platforms	Regional collaboration hubs with varying interoperability levels	Limited cross-border integration; primarily physical referrals
Data Management	Centralized European health data space with full interoperability	Regional data silos with selective sharing agreements	Institution-based data management with minimal external sharing
Regulatory Framework	Harmonized EU-wide digital health regulations and standards	Patchwork of national and regional regulations with partial harmonization	Traditional medical regulations with supplementary digital guidelines
Training Requirements	Comprehensive digital health curricula; new specializations in AI-assisted care	Variable training programs reflecting regional digital adoption levels	Incremental digital skills training within traditional education
Infrastructure Investment	High initial investment (€15–20 billion EU-wide); lower long-term operational costs	Moderate investment (€8–12 billion); higher operational complexity	Low investment (€3–5 billion); maintains existing infrastructure costs
Equity Implications	Risk of digital divide; requires targeted interventions for vulnerable populations	Variable equity outcomes depending on regional policies and resources	Maintains existing equity patterns; limited impact on access disparities
Quality Assurance	AI-driven continuous monitoring and standardized quality metrics	Mixed quality assurance combining digital and traditional methods	Traditional quality assurance with digital documentation support
Patient Autonomy	High patient control through digital platforms and data access	Variable patient empowerment depending on regional digital maturity	Traditional patient-provider relationships with limited digital empowerment
Innovation Capacity	Rapid innovation cycles; continuous AI improvement and feature development	Innovation concentrated in digital leader regions with slow diffusion	Incremental innovation within existing care frameworks
Resilience to Disruption	Vulnerable to cyber threats and system failures; requires robust backup systems	Moderate resilience through redundancy between digital and traditional systems	High resilience through maintained traditional infrastructure
Cost-Effectiveness	High long-term cost-effectiveness after initial investment period (ROI: 7–10 years)	Variable cost-effectiveness depending on regional implementation efficiency	Moderate cost savings through selective efficiency improvements

Critical uncertainties and their implications

Across all three scenarios, several critical uncertainties emerge that significantly influence the development and implementation of teleophthalmology solutions. These uncertainties, identified through analysis of current trends and emerging developments, include technological evolution, regulatory adaptation, professional resistance, and patient acceptance.

Technological uncertainties center on the pace and direction of innovation in areas such as artificial intelligence, diagnostic capabilities, and communication technologies. While current trends suggest continued rapid advancement in these areas, as documented by Topol [52], the specific capabilities that will emerge and their implications for eye care delivery remain uncertain. Regulatory uncertainties focus on how European and national authorities will adapt existing frameworks to address new technologies and care delivery models.

Professional acceptance represents another critical uncertainty, particularly regarding how healthcare providers will adapt to new roles and responsibilities. Drawing from the work of Susskind and Susskind [49] on the future of professions, this uncertainty encompasses questions about professional identity, expertise, and authority in an increasingly digital healthcare environment. Patient acceptance and trust in teleophthalmology solutions also remain uncertain, especially regarding privacy concerns and preferences for personal care delivery.

The implementation of teleophthalmology solutions across European borders raises additional considerations and challenges. Building upon the analysis of cross-border healthcare by Wismar et al. [59], these implications include legal and regulatory harmonization, data protection and sharing protocols, and professional qualification recognition. The scenarios must account for how different European healthcare systems can effectively collaborate while maintaining their distinct characteristics and requirements.

Strategic implications for key stakeholders

The three scenarios presented above carry distinct strategic implications for various stakeholders in the European healthcare ecosystem. Understanding these implications is crucial for developing adaptive strategies that can respond to different evolutionary pathways of teleophthalmology implementation.

In preparing for these diverse futures, EU policymakers must develop flexible regulatory frameworks that can accommodate different levels of digital transformation while maintaining core healthcare standards. Under Scenario A, the priority would be establishing comprehensive digital health governance structures, including standardized protocols for AI validation, cross-border data sharing agreements, and harmonized quality assurance mechanisms. This would require investment in pan-European digital infrastructure estimated at €15–20 billion over the next decade, with particular attention to ensuring universal broadband access and cybersecurity capabilities.

For Scenario B, policymakers should focus on creating adaptive governance mechanisms that allow for regional variation while maintaining minimum standards for interoperability and patient safety. This involves developing tiered regulatory frameworks that recognize different levels of digital maturity, establishing regional centers of excellence to support capability building, and creating flexible funding mechanisms that can support both digital transformation and traditional care enhancement. The strategy here emphasizes coordination rather than standardization, with investment in translation layers between different regional systems.

Under Scenario C, the strategic focus shifts to ensuring that technological enhancements do not exacerbate existing healthcare inequalities. This requires policies that support incremental innovation within existing healthcare structures, maintain professional autonomy while encouraging digital skill development, and ensure that technology adoption remains clinically driven rather than technology-led.

National healthcare authorities must develop contingency strategies that can adapt to different scenarios while maintaining healthcare system stability. In Scenario A, national authorities would need to fundamentally restructure healthcare delivery models, including redefining professional scopes of practice, establishing new reimbursement mechanisms for digital services, and developing comprehensive digital health literacy programs for both healthcare providers and patients. This transformation would require coordinated change management programs involving professional bodies, educational institutions, and patient organizations.

For Scenario B, national strategies should focus on identifying and leveraging regional strengths while addressing capability gaps. This involves conducting detailed digital readiness assessments across different regions, developing targeted support programs for digitally lagging areas, and establishing partnerships with digitally advanced regions for knowledge transfer and capacity building. National authorities would need to balance autonomy with coordination, allowing regions to pursue different digital transformation pathways while maintaining national healthcare objectives.

Under Scenario C, national authorities should prioritize strategic technology adoption that enhances rather than disrupts existing care models. This includes identifying specific pain points in current care delivery that

can be addressed through targeted technology solutions, supporting pilot programs that demonstrate clear clinical value, and ensuring that technology adoption aligns with professional preferences and patient needs.

Healthcare providers must develop adaptive capabilities that allow them to thrive under different scenarios. In Scenario A, providers need to fundamentally reimagine their service delivery models, investing in comprehensive digital transformation programs that encompass not only technology infrastructure but also organizational culture change, workforce retraining, and patient engagement strategies. This requires estimated institutional investments of €2–5 million for medium-sized eye care centers, with particular focus on developing AI integration capabilities and digital patient management systems.

For Scenario B, providers should develop flexible organizational structures that can adapt to varying levels of digital integration. This involves creating hybrid service delivery models that can seamlessly combine digital and traditional care, establishing partnerships with technology providers while maintaining clinical autonomy, and developing workforce strategies that support both digital natives and traditionally trained professionals. Providers in this scenario need to invest approximately €1–3 million in adaptive infrastructure that can scale up or down based on regional requirements.

Under Scenario C, providers should focus on selective technology adoption that enhances operational efficiency without disrupting clinical workflows. This includes investing in technologies that support existing practices (estimated €500,000–1 million for medium-sized centers), maintaining strong professional development programs that incrementally build digital skills, and ensuring that technology adoption is driven by clinical need rather than external pressure.

Technology developers must create solutions that can adapt to different implementation contexts. In Scenario A, the focus should be on developing comprehensive platforms that can handle end-to-end eye care delivery, with investments in advanced AI capabilities, interoperability standards, and user experience design. Companies should prepare for a market worth an estimated €8–10 billion annually by 2040, with high barriers to entry but significant returns for successful platforms.

For Scenario B, developers need to create modular solutions that can be configured for different regional requirements and integration levels. This involves developing flexible APIs that can connect with various systems, creating scalable solutions that can grow with regional digital maturity, and establishing regional partnerships for localized implementation support. The market opportunity here is estimated at €4–6 billion annually, with success dependent on adaptation capabilities.

Under Scenario C, technology developers should focus on creating point solutions that address specific clinical needs within traditional care models. This includes developing user-friendly tools that require minimal training, ensuring seamless integration with existing clinical workflows, and demonstrating clear ROI through efficiency improvements. The market size is estimated at €2–3 billion annually, with lower margins but more stable demand.

Healthcare professionals must prepare for different professional futures through strategic career development. In Scenario A, professionals should invest in developing digital health competencies, including AI collaboration skills, digital patient communication, and data interpretation capabilities. This transformation requires approximately 200–300 h of additional training over the next five years, with focus on understanding AI decision-making processes and managing digital patient relationships.

For Scenario B, professionals need to develop adaptive competencies that allow them to work across different digital environments. This includes building flexibility in practice patterns, developing skills in both digital and traditional care delivery, and maintaining professional networks that span different digital maturity levels. Training requirements vary by region but average 100–150 h of continuous professional development.

Under Scenario C, professionals should focus on selective digital skill development that enhances traditional practice. This involves identifying specific digital tools that improve clinical efficiency, maintaining core clinical competencies while adding digital enhancements, and participating in professional communities that share best practices for technology integration. Training requirements are modest at 40–60 h, focused on practical tool usage.

Patients and their representatives must prepare for different care delivery futures. In Scenario A, patient organizations should advocate for digital health literacy programs, ensure that vulnerable populations are not excluded from digital transformation, and participate in co-design processes for digital health solutions. Patients would need to invest time in developing digital health skills, estimated at 20–30 h of initial training plus ongoing learning.

For Scenario B, patient organizations should focus on ensuring equitable access across regions with different digital capabilities, advocating for patient choice in care delivery modalities, and supporting patients in navigating hybrid care systems. Patients would need to develop adaptive skills for engaging with both digital and traditional care, requiring 10–20 h of initial orientation.

Under Scenario C, patient organizations should ensure that technology adoption enhances rather than complicates patient experience, advocate for maintaining personal care relationships, and support patients who prefer traditional care models. Patient training requirements would be minimal at 5–10 h, focused on specific tool usage.

Critical analysis and discussion

The transformation of European eye care through teleophthalmology presents complex ethical, social, and practical challenges that warrant careful consideration. This section provides a critical analysis of these challenges while examining the broader implications for healthcare equity, professional practice, and societal values in the European context.

Ethical considerations in digital eye care delivery

The implementation of teleophthalmology across European healthcare systems raises significant ethical considerations that extend beyond traditional medical ethics. Drawing from Mittelstadt and Floridi's [38] comprehensive analysis of ethical challenges in digital healthcare, several key issues emerge that are particularly relevant to teleophthalmology implementation. The first concerns the fundamental transformation of the doctor-patient relationship in digital environments. As Beauchamp and Childress [2] argue in their seminal work on biomedical ethics, the principles of autonomy, beneficence, nonmaleficence, and justice must be carefully preserved and reconsidered in digital healthcare contexts.

The integration of artificial intelligence and automated diagnostic systems in teleophthalmology raises additional ethical concerns regarding accountability and decision-making. As documented by Char et al. [8] in their analysis of AI ethics in healthcare, questions arise about responsibility and liability when diagnostic decisions involve both human practitioners and AI systems. The European Union's approach to AI regulation, as outlined in the AI Act proposal (European [12, 13]), provides a framework for addressing these concerns but leaves many practical questions unanswered, particularly in healthcare applications.

Privacy considerations take on new dimensions in teleophthalmology, extending beyond traditional medical confidentiality to encompass data protection, storage, and sharing across borders. The work of Mittelstadt [37] on the ethics of biomedical big data highlights the challenges of balancing individual privacy rights with the potential benefits of large-scale data analysis for improving eye care delivery and outcomes. The implementation of the General Data Protection Regulation (GDPR) in Europe provides a robust framework for data protection, but its application to emerging teleophthalmology solutions requires careful consideration and ongoing adaptation.

Digital divide and healthcare equity

The potential impact of teleophthalmology on healthcare equity represents a critical area for analysis. While digital health solutions promise to improve access to eye care services, there is a risk of exacerbating existing healthcare disparities. Research by Weiss et al. [57] on digital health adoption patterns demonstrates that technological solutions can sometimes worsen healthcare inequities if not carefully designed and implemented with consideration for vulnerable populations.

The concept of digital health literacy, as explored by Norman and Skinner [40], becomes particularly relevant in the context of teleophthalmology. Their research indicates that successful engagement with digital health services requires not only access to technology but also the ability to effectively use and understand digital health tools. This consideration is especially important in the European context, where significant variations in digital literacy exist both within and between countries.

The geographical distribution of healthcare resources remains a critical concern, even with the implementation of teleophthalmology solutions. As documented by Schwebag [47] in their analysis of European healthcare accessibility, rural and remote areas often face significant challenges in accessing specialized medical care. While teleophthalmology offers potential solutions to these geographic disparities, careful attention must be paid to ensuring that digital solutions do not inadvertently create new forms of exclusion.

Professional identity and workforce implications

The transformation of eye care delivery through teleophthalmology has significant implications for professional identity and workforce development. Drawing from Abbott's [1] work on the system of professions, we can understand how technological change affects professional jurisdictions and expertise. The integration of teleophthalmology solutions requires healthcare professionals to adapt their roles and develop new competencies while maintaining their professional identity and authority.

Research by Dyrbye et al. [10] on healthcare workforce adaptation to digital technologies indicates that successful implementation of teleophthalmology requires significant changes in professional education and training. These changes must address not only technical skills but also the development of new approaches to patient communication and care delivery in digital environments. The work of Frenk et al. [17] on healthcare professional

education reform provides valuable insights into how educational systems can adapt to meet these evolving needs.

Cross-cultural considerations

The implementation of teleophthalmology across Europe must account for significant cultural variations in healthcare expectations and practices. Napier et al. [39], in their analysis of culture and health, demonstrate how cultural factors influence both healthcare delivery and patient engagement. These considerations become particularly important in the context of cross-border healthcare delivery enabled by teleophthalmology solutions.

The work of Hofstede et al. [25] on cultural dimensions provides a useful framework for understanding how different European cultures might respond to and engage with teleophthalmology services. Their research suggests that cultural attitudes toward technology, authority, and uncertainty can significantly influence the acceptance and effectiveness of digital healthcare solutions.

Technology as cultural transformation: beyond technical implementation

While our scenarios prominently feature technology as a key driver, we recognize and embrace the fundamental insight articulated by Mesko [35] that digital health is primarily a cultural transformation rather than a technological one. This perspective significantly influenced our framework development and scenario construction, though the technological dimension remains visible as the most tangible manifestation of deeper cultural shifts.

The choice to structure scenarios around varying degrees of technological integration was deliberate but not technologically deterministic. Rather, technology serves as a proxy for underlying cultural transformations in how societies conceptualize health, professional expertise, and care relationships. As Lupton [32] argues in her critical analysis of digital health, technologies are never neutral tools but are embedded within and shape social practices, cultural values, and power relationships.

In Scenario A (Fully Integrated Digital Eye Care), the extensive technological transformation reflects a profound cultural shift toward embracing algorithmic decision-making, distributed expertise, and reimagined patient autonomy. This scenario assumes not merely technological readiness but cultural acceptance of AI as a legitimate participant in clinical decision-making. The cultural transformation required here involves fundamental changes in how society defines medical expertise, moving from individual-embodied knowledge to hybrid human–machine intelligence. This aligns with Topol's [52] vision of"deep medicine"but extends beyond his technological focus to encompass the cultural prerequisites for such transformation.

Scenario B (Hybrid Model with Regional Variations) explicitly acknowledges that cultural readiness for digital transformation varies significantly across European regions. The technological variations described in this scenario are surface manifestations of deeper cultural differences in trust toward digital systems, preferences for personal versus mediated care relationships, and varying conceptualizations of privacy and data sharing. As documented by Hofstede et al. [25], European cultures differ significantly in uncertainty avoidance and power distance, factors that profoundly influence acceptance of digital health innovations. The hybrid model respects these cultural variations while enabling gradual cultural evolution through exposure and experience.

Scenario C (Technology-Enabled Traditional Care) represents cultures that prioritize continuity, personal relationships, and gradual adaptation. The limited technological integration in this scenario reflects not technological conservatism but cultural values that emphasize the irreplaceable nature of human clinical judgment and the therapeutic value of in-person care relationships. This scenario acknowledges what Frank [16] calls the"moral dimension"of medical practice, where healing involves not just technical intervention but human presence and witness.

Our framework also recognizes that successful teleophthalmology implementation requires cultural transformation across multiple dimensions:

> Professional Culture: The shift from individual clinical autonomy to collaborative human-AI decision-making represents a fundamental cultural change in medical practice. As Susskind and Susskind [49] argue, professions must culturally reimagine their role from exclusive knowledge guardians to facilitators of distributed expertise. This cultural shift precedes and enables technological implementation rather than following from it.
>
> Patient Culture: The transformation from passive care recipients to active health data managers requires significant cultural change in how individuals conceptualize their role in healthcare. This involves not just digital literacy but what Ruckenstein and Schüll [45] term"data sense-making"– the cultural capacity to interpret and act upon digital health information. The scenarios reflect different degrees of this cultural transformation, from full embrace in Scenario A to selective engagement in Scenario C.
>
> Organizational Culture: Healthcare institutions must undergo cultural transformation from hierarchical, department-based structures to net-

worked, data-driven organizations. As Wachter [56] documents in"The Digital Doctor,"this cultural shift often proves more challenging than technical implementation. Our scenarios reflect varying degrees of organizational cultural readiness for such transformation.

Societal Culture: Broader societal values regarding privacy, solidarity, and healthcare as a public good significantly influence teleophthalmology implementation. The European context, with its strong tradition of solidarity-based healthcare systems, requires different cultural adaptations than market-based systems. As Prainsack and Buyx [43] argue in their work on solidarity in healthcare, digital transformation must align with existing cultural values while potentially reshaping them.

Understanding digital health as cultural transformation has profound implications for implementation strategy. Rather than focusing primarily on technological deployment, successful teleophthalmology implementation requires:

1. Cultural Preparation: Investment in cultural change programs that address professional identity, patient empowerment, and organizational transformation before or alongside technological implementation
2. Value Alignment: Ensuring that technological solutions align with and respect existing cultural values while creating space for cultural evolution
3. Narrative Construction: Developing compelling narratives that help stakeholders understand and embrace new roles and relationships in digitally-mediated care
4. Cultural Mediators: Identifying and supporting cultural change agents who can bridge between traditional and digital care cultures
5. Gradual Cultural Evolution: Recognizing that cultural transformation occurs more slowly than technological change and planning implementation timelines accordingly

This cultural perspective explains why identical technologies may produce vastly different outcomes across European regions, as reflected in our scenario variations. It also suggests that the critical success factor for teleophthalmology is not technological sophistication but cultural readiness and adaptation capacity. By foregrounding technology in our scenarios while understanding it as a manifestation of deeper cultural transformation, we provide a framework that is both practically actionable and theoretically sophisticated.

Data sovereignty and European values

The question of data sovereignty emerges as a critical consideration in the implementation of teleophthalmology across Europe. Regarding health data governance, the management and control of medical data must align with European values and regulatory frameworks while enabling effective cross-border healthcare delivery. The European Health Data Space initiative (European [14]) provides a framework for addressing these concerns, but significant challenges remain in its practical implementation.

Future implications and adaptations

Looking forward, the success of teleophthalmology implementation will depend on the ability to address these various challenges while maintaining focus on improving patient care and outcomes. The work of Greenhalgh et al. [22] on technology implementation in healthcare settings suggests that successful adoption requires careful attention to both technical and social factors. Their NASSS framework (Non-adoption, Abandonment, Scale-up, Spread, and Sustainability) provides valuable insights into how these challenges might be addressed in practice.

Conclusion

The transformation of European eye care through teleophthalmology represents a complex socio-technical transition that will significantly reshape healthcare delivery over the coming decades. Through our analysis and the development of a comprehensive conceptual framework, we have identified key pathways, challenges, and opportunities that will influence this transformation. As we conclude this examination of teleophthalmology's future in Europe, several crucial insights emerge that warrant emphasis and consideration.

The multi-level framework developed in this paper demonstrates that successful implementation of teleophthalmology requires careful attention to interactions between macro-level policy environments, meso-level healthcare systems, and micro-level clinical practices. As Greenhalgh et al. [22] have shown in their analysis of healthcare technology adoption, the alignment of these different levels is crucial for successful digital health transformation. Our analysis suggests that while technological capabilities will continue to advance rapidly, the pace of social and institutional adaptation will likely determine the ultimate success of teleophthalmology implementation.

The scenarios presented in this paper highlight the range of possible futures for European eye care, from fully integrated digital systems to more modest

technology-enabled enhancements of traditional care models. As van der Heijden [53] argues in his work on scenario planning, the value of such scenarios lies not in their predictive accuracy but in their ability to help stakeholders prepare for different possible futures. Our analysis suggests that the most likely outcome will involve significant regional variation in teleophthalmology adoption and implementation, reflecting the diverse healthcare contexts and capabilities across Europe.

Critical challenges identified through our analysis include the need to address healthcare equity concerns, ensure appropriate data governance, maintain high standards of care, and support professional adaptation to new care delivery models. As documented by Ricciardi et al. [44] in their examination of digital health governance, these challenges require coordinated action at both European and national levels. The success of teleophthalmology implementation will depend largely on how effectively these challenges are addressed through policy, professional development, and technological innovation.

Looking forward, several research priorities emerge from our analysis. First, there is a need for more detailed examination of how different European healthcare systems can effectively coordinate teleophthalmology implementation while maintaining their distinct characteristics and requirements. Second, research is needed to better understand how professional roles and responsibilities will evolve in response to increasing digitalization of eye care services. Finally, ongoing assessment of the impact of teleophthalmology on healthcare outcomes and equity will be crucial for guiding future development and implementation.

The implications of this research extend beyond ophthalmology to inform broader discussions about the future of healthcare delivery in Europe. As Topol [52] argues in his analysis of digital medicine, the transformation of medical specialties through digital technologies will require fundamental reconsideration of how healthcare is organized, delivered, and evaluated. Our framework and analysis provide a structured approach for understanding and managing this transformation within specific medical specialties while maintaining awareness of broader healthcare system contexts.

For policymakers and healthcare leaders, this research highlights the importance of developing flexible and adaptive approaches to teleophthalmology implementation. Rather than seeking a one-size-fits-all solution, success will require careful attention to local contexts while maintaining sufficient standardization to enable cross-border care delivery and data sharing. The work of Brigitta [7] on cross-border healthcare collaboration provides valuable insights into how such balance might be achieved.

The comparative analysis of scenarios suggests several cross-cutting strategies for policymakers, healthcare providers, and technology developers. In a fully integrated future (Scenario A), emphasis should be placed on building robust pan-European digital infrastructures, harmonizing regulatory frameworks, and ensuring AI systems are transparent and accountable. In hybrid contexts (Scenario B), targeted investment in lagging regions, capacity-building for healthcare professionals, and the creation of regional centers of excellence can help narrow disparities. For technology-enabled traditional care (Scenario C), gradual integration strategies, such as embedding teleophthalmology tools into existing workflows, incentivizing professional upskilling, and fostering patient digital literacy, can preserve trust while laying the groundwork for deeper transformation. Across all scenarios, proactive governance, inclusive stakeholder engagement, and continuous evaluation will be critical to aligning technological potential with healthcare equity and quality objectives.

In closing, the future of teleophthalmology in Europe holds great promise for improving access to eye care services and enhancing care quality through digital innovation. However, realizing this promise will require careful attention to the complex interplay of technological, social, and institutional factors identified in our analysis. As Europe continues to lead in healthcare innovation and cross-border cooperation, the evolution of teleophthalmology will serve as an important case study in how digital technologies can be effectively integrated into healthcare systems while maintaining commitment to equity, quality, and patient-centered care.

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