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digital hollywood university

Editor's Preface to the Third Volume of DHU International Journal

As the DHU International Journal enters its third volume, we are pleased to see its continued growth as a platform for sharing research and practice in digital communication, design, and education. Although still a young publication, the journal has begun to establish its identity as an international venue for academic exchange, reflecting the expanding research engagement of faculty members, graduate students, and graduates.

In this issue, the number of full-paper submissions has increased, reflecting the journal's growing recognition as an international academic platform. While no full research articles are included in this issue, several manuscripts were reviewed and accepted as Research Notes. These papers, although slightly lacking in focus or logical depth to qualify as full articles, demonstrate strong research potential. It is also noteworthy that several submissions were contributed by graduates of the university's master's program, showing that research activities are extending beyond the campus into professional and academic practice.

This trend also aligns with editorial revisions introduced in this volume. Starting from Volume 12, the category previously labeled as "Reports" up to the previous issue has been redefined as "Research Reports." This change reflects a shift in focus—from simple activity reports to papers with the characteristics of research reports that possess the potential to contribute to future studies. Manuscripts submitted under this category were evaluated and accepted in accordance with these revised standards. In line with this policy, the Editorial Committee selected papers that address issues in educational settings from both practical and analytical perspectives.

In recent years, AI-assisted tools have begun to bridge language barriers in international academic communication. This development is expected to enable a more diverse range of researchers to share their work and insights across borders. We look forward to future contributions that embody this growing inclusivity and global exchange of ideas.

Atsuko K. YAMAZAKI

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Research Note

The Transformation of Subtitled Viewing Habits and the Growing Reception of Asian Visual Content

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This study examines the historical aversion to subtitles in the English-speaking world and explores how this perception has evolved with the rise of global streaming platforms. The research combines survey data from Japanese audiences with interviews conducted with more than 100 online English instructors working on international learning platforms. The findings indicate that subtitle literacy—defined as the ability to process and appreciate subtitled audiovisual content—has grown significantly, particularly among younger viewers. This shift is attributed to the widespread use of VOD services, social media engagement, and mobile viewing, all of which normalize multitasking and cross-linguistic exposure. Once viewed as distracting, subtitles now function as cultural and narrative bridges that facilitate global content circulation. The study concludes by emphasizing the importance of user experience design and creative subtitling strategies in enhancing accessibility and intercultural understanding in global media communication.

1. The Background and Transformation of Subtitling Aversion in the English-Speaking World

Historically, the act of "reading subtitles" has not been a common viewing behavior in the English-speaking world. This tendency is rooted in structural factors shaped by the unique media ecology of Anglophone countries. In the United States and the United Kingdom, domestically produced audiovisual content in English has long dominated television and film, while foreign-language works have been confined to limited screenings in cinemas and niche programming slots on television[5]. Such an environment inherently restricted exposure to non-English content, limiting the necessity of engaging with subtitles.

Educational practices in English-speaking countries have also contributed to this pattern. In many Anglophone education systems, the development of oral comprehension and conversational skills has traditionally been prioritized over the cultivation of visual-linguistic processing skills. As a result, the act of reading on-screen text has not been embedded as a routine or natural component of media consumption. In contrast to the Japanese "telop" culture—where variety shows frequently display on-screen captions—English-language television has maintained a relatively low reliance on textual elements[6].

Cultural and psychological factors further reinforced the aversion to subtitles. Within the historical context of Hollywood's global dominance, subtitles were often associated with foreign-language "art house" films, which were stereotyped as niche, intellectually demanding, or inaccessible to general audiences[7]. In American culture, the perception that "reading is work" has also shaped leisure practices: reading during entertainment media consumption was often seen as incompatible with relaxation. Consequently, between the 1980s and the early 2000s, many foreign films released in the United States were predominantly offered in dubbed versions rather than subtitled formats.

In recent years, however, the proliferation of streaming platforms and the ubiquity of mobile devices have driven a profound shift in viewing habits, particularly among younger audiences. Subtitling is increasingly accepted as a natural part of audiovisual consumption. The rise of social media and short-form video platforms has normalized silent viewing with captions, making the presence of on-screen text an expected component of the media experience. Platforms such as TikTok, Instagram, and Facebook routinely employ automatic captions to ensure content is understandable across varied viewing environments, fostering habits of visual information processing[1].

Empirical evidence supports this shift. According to a Netflix user analysis (2021), approximately 80% of subscribers utilize subtitles in some form, with 40% regularly keeping English subtitles enabled for English-language content (Morning Consult, 2021). Similarly, a 2021 report by the UK's Ofcom found that more than half of viewers aged 18–34 actively use subtitles, confirming the growing subtitle literacy among younger generations (Ofcom, 2021).

Globalization has also contributed to this transformation by increasing linguistic diversity within English-speaking populations. The rise of non-native English speakers and the proliferation of diverse accents have made sole reliance on auditory comprehension more challenging. English subtitles are increasingly functioning as an essential, rather than supplementary, component of media consumption. Even among native speakers, factors such as regional dialects, slang, rapid speech, or overlapping background music have amplified the practical value of subtitles for accurate comprehension.

In this way, subtitles are evolving from a tool of cross-linguistic translation into a visual medium that accommodates intralingual diversity. The normalization of subtitling in the English-speaking world reflects both growing linguistic pluralism and the broader shift toward non-audio-centric information consumption. This cultural transformation fosters subtitle literacy among Anglophone audiences and, in turn, creates new pathways for the global circulation and acceptance of non-English audiovisual content, including media from Asia.

2. The Mainstreaming of VOD and Subtitled Viewing: The Rise of Subtitle Literacy

2.1 Traditional Subtitling Practices Among English-Speaking Audiences

Historically, English-speaking audiences have not regarded subtitled viewing as a mainstream practice. In cinemas across the United States, Canada, the United Kingdom, and Australia, English-language films have overwhelmingly dominated the screens, while non-English films were relegated to limited releases or niche art house circuits[2]. As a result, most viewers lacked regular exposure to subtitles and often avoided them, citing reasons such as "subtitles are distracting" or "they make it difficult to focus on the screen."

The rapid expansion of Video-on-Demand (VOD) platforms such as Netflix, Amazon Prime Video, and Disney+ has transformed this landscape. VOD allows users to freely select audio and subtitle options, and English speakers have increasingly adopted the practice of pairing English audio with English subtitles. Interviews conducted with online English instructors for an online English-learning platform revealed that subtitles are frequently used for practical reasons: watching late at night without sound, difficulty hearing dialogue over background music and sound effects, understanding dialects and slang, or following content while multitasking.

This trend is supported by platform data. According to Netflix (2021), approximately 80% of users engage with subtitles in some capacity—a figure reflecting a general trend toward increased subtitle usage, although the breakdown between language types and frequency was not fully detailed, and about 40% keep English subtitles permanently enabled even when watching English-language content[3]. Likewise, the UK's Ofcom (2021) reported that over half of viewers aged 18–34 actively use subtitles, indicating that subtitled viewing has become normalized among younger audiences[4]. These findings collectively point to the emergence of a generation of English-speaking viewers with higher "subtitle literacy," for whom visual textual processing has become a routine part of media consumption.

2.2 Subtitle Familiarity and the Reception of Asian Content

The widespread adoption of same-language subtitling has substantially reduced the psychological resistance of English-speaking audiences toward subtitled content. Behaviors that were once considered disruptive to immersion—such as "having to read while watching"—are increasingly perceived as natural. As a result, the barrier to engaging with non-English audiovisual content has been significantly lowered.

This growing subtitle familiarity is closely tied to the international success of recent Asian media. For instance, Parasite achieved both commercial success and critical acclaim in the U.S., culminating in an Academy Award for Best Picture, despite being entirely subtitled. Similarly, titles such as Squid Game and Shōgun have gained global popularity through simultaneous VOD releases, with social media amplification driving viral engagement across English-speaking markets.

These cases illustrate the synergistic effect of two factors: the high production value of Asian audiovisual content and the willingness of a new generation of English-speaking viewers to embrace subtitled media as part of their everyday viewing habits. This convergence suggests that subtitle literacy is not merely a linguistic adaptation but also a cultural shift that facilitates the global circulation of non-English media[3] .

3. Research Methodology

3.1 Data Sources and Methodological Approach

The discussion in this study is based on the analysis of two complementary datasets. The first is a quantitative survey on subtitled viewing conducted in Japan by CCCMK Holdings, a professional market research firm. The second consists of qualitative interviews conducted by the author between 2021 and 2024, which were designed to interpret and extend the insights obtained from the Japanese survey. These interviews were conducted with English instructors from more than 50 countries through the online English-learning platform. The following sections detail these two research components.

3.2 Survey on Subtitled Viewing Behavior in Japan

The first dataset derives from the Survey on Subtitled Viewing of Audiovisual Content, conducted jointly by Digital Hollywood University and CCCMK Holdings in January 2025. The survey targeted Japanese residents aged 15 to 69 and was administered online using an internet-based panel method. A total of 1,805 valid responses were collected. The sample was evenly stratified by age and gender, with 100 respondents from each demographic segment. To capture the anticipated prevalence of subtitled viewing among younger cohorts, additional oversampling was conducted for "university students" and respondents in their twenties, with 200 supplementary participants in each group.

The questionnaire consisted of 4 screening questions and 13 main items, designed to capture both behavioral and attitudinal aspects of viewing practices and subtitle usage. Table 1 summarizes the demographic characteristics of the respondents, including age, gender, and occupation. High school and university/graduate students were classified by educational status rather than age category. All participants reported viewing audiovisual content—via television or online streaming platforms—at least once every two to three months.

Table 1: Age and Gender Distribution of Respondents in the Survey on Subtitled Viewing of Audiovisual Content

Participants	Male		Female	
High School Students	100	6%	100	6%
University & Graduate Students	201	11%	200	11%
20s	201	11%	200	6%
30s	100	6%	101	6%
40s	101	6&	10	6%
50s	100	6%	101	6%
60s	100	6%	100	6%
Total	903	50%	902	50%

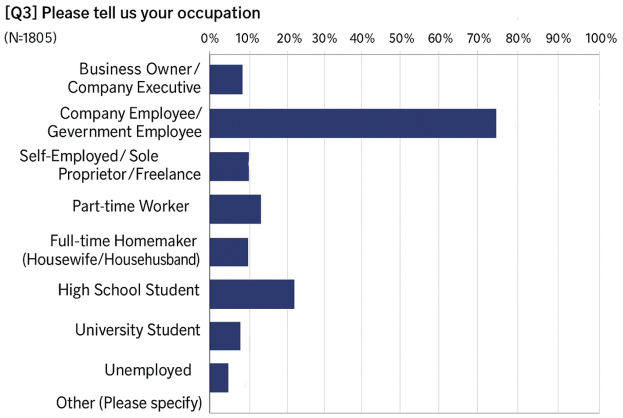

Figure 1: Occupational Distribution of Respondents in the Survey on Subtitled Viewing of Audiovisual Content

3.3 Survey of English Subtitle Usage Among Online English Instructors

This component of the study aimed to investigate the actual practices and cultural contexts of subtitle usage among native English speakers. To achieve this, we conducted an interview-based survey targeting online English instructors affiliated with Online English conversation service, representing a diverse range of national backgrounds. The participants comprised 112 instructors from over 50 countries (39% male, 61% female), ranging in age from their 20s to 50s.

Data collection employed a mixed-method approach, including Zoom interviews, Google Forms questionnaires, and open-ended responses via Slack chat. The instructors' countries of origin included the United States, Canada, the United Kingdom, Ireland, Australia, South Africa, Benin, Lebanon, and Hungary, among others.

The survey consisted of multiple exploratory items designed to capture both behavioral and cultural dimensions of subtitle use

(1) Whether participants use English subtitles when viewing audiovisual content,

(2) Their preference between dubbing and subtitling, and

(3) Perceived generational or cultural differences in subtitle usage trends.

Open-ended responses formed the core of the dataset, allowing participants to elaborate on their motivations for using (or not using) subtitles, the types of media consumed (e.g., films, anime, YouTube), and viewing practices such as multitasking, variable playback speed, or coping with low volume or background noise. These qualitative insights were used as foundational data to explore international diversity in viewing habits and perceptions of subtitling culture.

Table 2: summarizes the distribution of respondents by nationality and age group

	Age			
	< 30	**−40**	**40+**	**Total**
US	6	7	0	13
Canada	1	0	1	2
UK	2	2	0	4
South Africa	6	0	0	6
Australia	1	0	0	1
Ireland	0	1	0	1
New Zealand	0	0	0	0
Total	16	10	1	27

4. Findings

4.1 Survey on Subtitled Viewing of Audiovisual Content Among Japanese Audiences

In the survey, participants were asked whether they watch Japanese audiovisual content with Japanese subtitles. Among respondents, 11.9% answered that they watch with subtitles "almost every time," 14.2% "frequently," and 22.7% "occasionally." Combined, 48.8% of respondents reported using Japanese subtitles for Japanese-language content to some degree. Conversely, 51.2% stated that they "never" watch with subtitles, suggesting a polarized pattern of viewing behaviors (Figure 2).

The reasons for watching Japanese audiovisual content with Japanese subtitles are summarized in Figure 3 and can be categorized into four main themes:

(1) Physical or environmental constraints that make listening difficult or require muted playback:
  (a) Difficulty hearing due to surrounding noise (26.8%)
  (b) Watching in transit where audio cannot be played (14.1%)
  (c) Viewing in workplaces or restaurants where audio is restricted (9.8%)
  (d) Watching without earphones in environments where speakers cannot be used (14.9%)
  (e) Muting or reducing audio at home out of consideration for family members (12.3%)

(2) Enhancing speech intelligibility or linguistic comprehension:
  (a) Difficulty hearing dialogue overlapping with background music or sound effects (20.7%)
  (b) Difficulty understanding voices due to dialects, speech patterns, or tone (25.8%)
  (c) Need for support in understanding technical or specialized terms (21.7%)

(3) Improving the quality of the viewing experience:
  (a) Understanding scripts and dialogue more accurately and deeply (24.2%)
  (b) Feeling that reading subtitles makes content more enjoyable or memorable (23.0%)
  (c) Responses related to viewing styles are summarized in Figure (4) including tendencies toward fast-forwarding or focusing on visuals or audio only. Viewing contexts, shown in Figure 5, indicate that multitasking is common: 63.7% watch content "while eating," 35.8% "while doing housework or getting ready," and 22.1% "as background while working or studying."

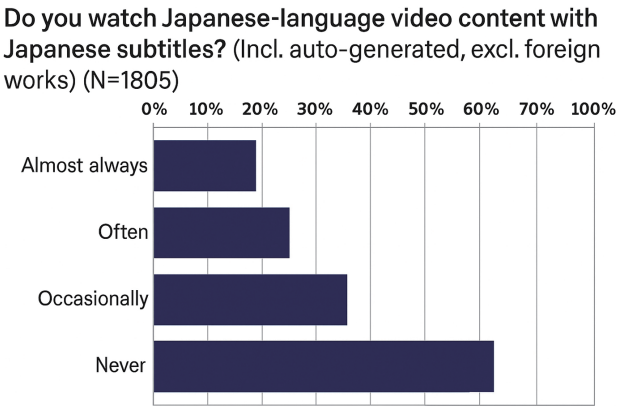

Figure 2: Responses on Watching Japanese Audiovisual Content with Japanese Subtitles

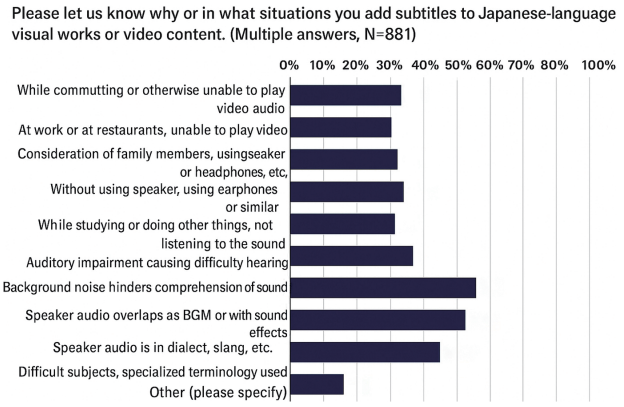

Figure 3: Reasons Reported for Watching Japanese Audiovisual Content with Japanese Subtitles

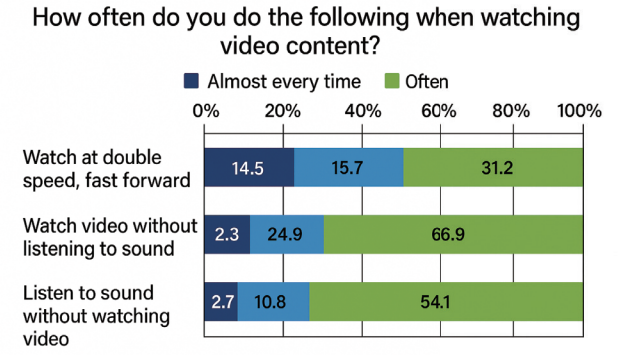

Figure 4: Responses on Fast-Forwarding, Visual-Only, and Audio-Only Viewing of Audiovisual Content

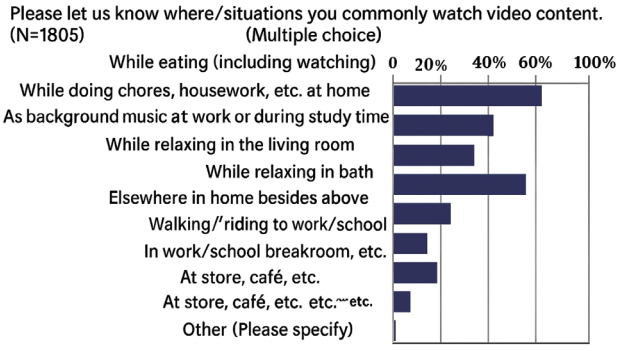

Figure 5: Responses Regarding Locations and Situational Contexts When Watching Audiovisual Content

4.2 Survey of English Subtitle Usage Among Online English Instructors

As shown in Table 3, the proportion of respondents who reported "regularly using" English subtitles exceeded 50% in all surveyed countries: 71% in the United Kingdom, 68% in the United States, 66% in Australia, 62% in Canada, and 54% in South Africa. While South Africa also displayed a relatively higher preference for dubbing, its overall rate of subtitle usage remained high.

Table 4 summarizes the types of content viewed with subtitles and the primary reasons for using them, broken down by nationality. Across all groups, the most frequently cited reason for using subtitles was comprehension, followed by background noise as the second most common factor.

Table 3: Patterns of Subtitle and Dubbing Usage Across Five English-Speaking Countries

Country	Use English Subtitles Often (%)	Prefer Dubbing (%)	Use Both (%)
US	68	20	12
Canada	62	25	13
UK	71	18	11
South Africa	54	30	16
Australia	66	21	13

Table 4: Types of Content and Reasons for Subtitle and Dubbing Usage in Five English-Speaking Countries

	Sub				No Sub	Reason							Sub	Dub
	Live	Anime	Game	You Tube		Comp.	Noise	Mobil	Skip	Multi -task	Dia -lect	Volu -me		
US	13	5	2	7	0	7	7	3	2	2	5	3	8	1
Canada	1	1	0	0	1	1	1	0	0	0	1	0	0	0
UK	3	1	0	1	1	3	1	0	0	0	1	0	1	0
South Africa	4	4	0	2	2	4	1	0	0	0	4	2	4	0
Australia	1	1	0	0	0	1	0	0	0	0	1	0	0	0
Ireland	0	0	0	0	1	0	0	0	0	0	1	0	0	0
New Zealand	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	22	12	2	10	5	16	10	3	2	2	13	5	13	1

5. Discussion

5.1. Findings from the Survey on Subtitled Viewing Among Japanese Audiences

The survey results reveal a polarized pattern of viewing behavior: nearly half of respondents reported watching Japanese audiovisual content with Japanese subtitles, while a similar proportion stated that they "never" use subtitles. The reasons for watching Japanese content with Japanese subtitles are diverse but can be organized into four key categories.

First, a significant proportion of respondents use subtitles in situations where physical or environmental factors make listening difficult or discourage the use of audio. This indicates that subtitles function primarily as a viewing aid, closely tied to urban lifestyles and the increasing prevalence of mobile viewing contexts. Second, subtitles are employed to address limitations in auditory clarity and linguistic comprehension. Even for native speakers, the responses indicate a growing awareness that subtitles can support the accurate understanding of content. Those who actively use subtitles do so not only to compensate for inaudible dialogue but also to enhance the overall quality of the viewing experience, reflecting the role of subtitles as cognitive and interpretive tools.

Third, the findings highlight a strong affinity between subtitles, social media use, and multitasking behavior. A defining characteristic of contemporary viewing habits is simultaneous media consumption, such as watching videos while browsing social media or using other applications. Under such conditions, reliance on auditory information alone becomes challenging, and subtitles provide an effective visual complement. The proliferation of smartphones and tablets has normalized this "multitasking viewing" behavior, which diverts attention away from audio and reinforces the functional importance of subtitles as a primary channel of comprehension.

Finally, the survey illustrates how changes in viewing behavior are reshaping the role and function of subtitles. Subtitles are

no longer perceived merely as a supplementary tool but are increasingly central to the viewing experience, especially in dispersed-attention environments. For instance, 61.4% of respondents reported engaging in accelerated viewing—combining those who answered "almost always" (14.5%), "frequently" (15.7%), and "occasionally" (31.2%)—indicating a clear preference for efficient, time-compressed information consumption. Additionally, a notable proportion reported deliberately decoupling audio and visual elements in their media use, with 27.4% "watching without listening to audio" and 13.5% "listening without watching visuals."

These findings suggest that subtitles have evolved into a primary visual medium for comprehension, reflecting a structural transformation in media engagement from traditional passive "audio-visual" viewing to more flexible and active forms of information acquisition. Consequently, future approaches to subtitle design and audiovisual user interfaces (UI) will need to account for increasingly diversified and multitask-oriented viewing practices[5].

5.2. Survey of English Subtitle Usage Among Online English Instructors

The findings of this survey suggest that subtitles, once regarded in the English-speaking world as "distracting" or "a hindrance to viewing," are now increasingly accepted as a standard supportive feature. The survey of Japanese audiences revealed that the tendency to watch domestic audiovisual content with same-language subtitles is particularly pronounced among younger generations. This pattern appears to be driven by shifts in lifestyle, attention to comprehension, evolving media habits, and the rise of subtitle literacy.

A similar transformation is evident in English-speaking contexts. English speakers are progressively adopting the habit of watching English-language content with English subtitles, which in turn has familiarized them with reading subtitles and likely reduced their psychological resistance to non-English audiovisual content. According to Ofcom (2021), more than half of viewers aged 18–34 in the United Kingdom reported that they "actively use" subtitles, indicating a clear generational gap in subtitle literacy[4].

5.3. Subtitling Culture and a Turning Point in Audiovisual Reception

One plausible explanation for the recent increase in the acceptance of non-English audiovisual content in the English-speaking world is the widespread adoption of the practice of watching English-language content with English subtitles. Both the interviews with online English instructors and the domestic audience survey confirm that this viewing style has become increasingly common, particularly among younger generations. The rise of this practice is closely linked to the proliferation of VOD platforms and the emergence of new media environments, including social networking services (SNS). In contexts where audio cannot be played, or in multitasking situations characterized by "ambient viewing," audiences actively rely on subtitles as a visual complement. This shift is not merely a matter of convenience; it reflects a growing frequency of English-speaking audiences encountering cross-cultural contexts and linguistic nuances through subtitles.

Subtitle literacy has contributed to a broader transformation in audiovisual literacy, expanding traditional models of comprehension toward more layered and multimodal engagement. Traditional reception, which relied primarily on the dual channel of "audio + visuals," is shifting toward a tri-layered comprehension model of "audio + visuals + text." Viewers are increasingly developing the ability to process multiple layers of media simultaneously. This indicates a reduction in the psychological and cognitive barriers to "reading" audiovisual content, rather than a simple technological evolution in subtitling[1].

Notably, streaming platforms such as Netflix and Amazon Prime have made "English audio + English subtitles" a highly accessible and increasingly common configuration, often remembered by user preference and frequently used by younger viewers. This interface architecture encourages subtitled viewing even without explicit user selection, structurally guiding audience behavior. In fact, Netflix's 2021 official report indicated that approximately 80% of users employ subtitles in some form, and around 40% keep English subtitles permanently enabled for English-language content[2]. This demonstrates that subtitled viewing is no longer a matter of individual preference but has become a cultural practice shaped by technology and UI strategy.

Such developments have dramatically lowered the psychological barrier to subtitles for English-speaking audiences, creating a receptive environment for non-English audiovisual works such as Parasite, Squid Game, and Shōgun. Consequently, the current transformation of subtitling culture represents more than the evolution of a supplementary technology; it signifies a shift in information-processing modalities and a reconfiguration of the global circulation structure of audiovisual content. These findings have profound implications for the future of translation subtitling, UI/UX design, and the creative strategies that underpin global media distribution.

5.4. A Comparative Perspective on Subtitling Culture in the English-Speaking World and Japan[4]

A persistent cultural attitude in the United States has been encapsulated in the notion that "reading is work", implying that the act of reading is cognitively effortful and thus incompatible with relaxation-oriented entertainment such as films and television dramas. This perspective contributed to a long-standing reluctance toward subtitles, particularly in leisure contexts. Indeed, from the 1980s through the early 2000s, the majority of foreign films screened in U.S. theaters were presented in dubbed versions, reflecting the prevailing preference to avoid on-screen reading. Such aversion to subtitles historically functioned as a barrier preventing English-speaking audiences from engaging with high-quality non-English audiovisual works.

By contrast, several factors have facilitated the broader acceptance of subtitling in Japan:

(1) Influence of Education and Media Habits

Japanese schooling traditionally emphasizes reading comprehension, fostering habits of processing information through written text. Additionally, the pervasive "telop" culture—frequent use of on-screen captions in television programs, variety shows, and even YouTube content—has normalized visual textual support. As a result, Japanese audiences exhibit little resistance to subtitles, accelerating their adoption as a natural part of the viewing experience.

(2) National Disposition Toward Precision and Detail

Japanese audiences demonstrate a strong inclination to receive information accurately and often express discomfort with ambiguous or partially audible dialogue. This tendency to rely more on textual information than purely auditory cues aligns with a precision-oriented media culture, which actively encourages the use of subtitles to ensure full comprehension.

Together, these educational, cultural, and psychological factors illustrate why subtitled viewing has been more readily internalized in Japan than in many English-speaking countries, and they provide a comparative framework for understanding global differences in subtitling culture[4]

6. Future Perspectives and Recommendations

6.1. Redefining the Role of Translation Subtitles

In recent years, subtitles have been increasingly redefined not merely as linguistic bridges but as creative media elements that complement the narrative, aesthetic, and immersive qualities of audiovisual works. Streaming platforms such as Netflix and Amazon Prime have popularized the concept of "creative localization," which goes beyond literal translation to convey cultural nuance and resonate with the sensibilities of target audiences.

For instance, culturally specific terms such as the Japanese senpai or the Korean oppa cannot be fully conveyed through direct translation. Subtitle creators must adopt a range of strategies—such as paraphrasing, selective retention, or explanatory cues—to preserve the intended cultural nuance. This requires not only linguistic expertise but also a creative sensibility aligned with the work's direction and emotional tone.

Furthermore, the design of subtitles as part of the overall user experience (UX) has grown increasingly important. Visual elements—including font style, color, size, and timing of appearance—contribute significantly to how viewers perceive and process subtitled content. Decisions on how to represent aspects of spoken delivery—such as emphasis, emotional inflection, sarcasm, shouting, or whispering—can directly influence viewer immersion and emotional engagement.

6.2 Strategic Recommendations for Content Creators and Streaming Platforms

The global dissemination of Asian films and dramas increasingly depends on the implementation of three key subtitling strategies:

(1) Enhanced Multilingual Support

Expanding beyond English to offer simultaneous subtitle releases in major languages such as Spanish, French, and Arabic can significantly broaden international audience reach.

(2) Explanatory Translation Techniques

Employing techniques such as "tooltip subtitles," dual-line subtitles, or brief annotation subtitles allows for the delivery of concise cultural context—such as customs or background references—while maintaining viewer immersion. This approach facilitates cross-cultural understanding without disrupting the narrative flow.

(3) Subtitle Design Integrated with Audio

Synchronizing subtitle timing, color, and visual emphasis with music and sound effects can create a visually and aurally unified user experience (UX), enhancing emotional resonance and narrative impact.

These strategies embody a new production paradigm that treats subtitles not simply as linguistic aids, but as visual narration, integrated into the creative design of audiovisual storytelling.

6.3 Challenges of International Distribution and Localization for Japanese Cinema

While Japanese cinema has achieved notable international success in the field of animation, live-action films continue to face linguistic and cultural barriers that limit their global reach. Elements such as the nuances of honorific speech and ambiguous interpersonal references often resist direct translation, resulting in subtitled versions that fail to fully convey relational dynamics or emotional subtleties.

To enhance the international dissemination and reception of Japanese live-action films, several measures are essential:

(1) Development of subtitle creators with cultural and creative literacy, capable of functioning as hybrid professionals bridging translation and direction.

(2) Close collaboration between directors, screenwriters, and translators, ensuring that subtitling design reflects the intended narrative and emotional direction of the work.

(3) Localization strategies informed by audience reception trends in each target country, tailoring subtitles to cultural expectations and viewing habits.

Advancing a comprehensive and sophisticated subtitling policy that integrates these elements will be crucial to securing stronger international recognition and appreciation for Japanese live-action cinema.

7. Conclusion

This study examined the growing prevalence of English speakers watching domestic content with English subtitles and explored how this shift has influenced the reception of non-English audiovisual works, particularly Asian productions. Through interview surveys conducted via Online English conversation service and analyses of audience behavior data, the study demonstrates that changes in VOD-era viewing environments, the rise of social media culture, and the increasing demand for visual information support have collectively fostered the establishment of subtitle literacy among English-speaking audiences.

Once regarded in the Anglophone world as "distracting" or "cognitively burdensome," subtitles are now widely accepted as part of a standard viewing practice, especially among younger generations. This transformation has lowered the psychological barriers to foreign-language content, contributing to the global success of Asian works such as the Korean film Parasite, the Netflix drama Squid Game, and the Japan-set series Shōgun.

Moreover, the findings highlight that subtitles are being redefined not merely as tools of linguistic conversion but as integral components of audiovisual direction and user experience design. In particular, streaming platforms that present "English audio + English subtitles" as a default configuration have structurally reshaped viewing behavior, signaling a broader cultural evolution in audiovisual engagement[2].

Looking forward, the successful global distribution of Japanese and other Asian audiovisual works will require a subtitling strategy that integrates translation competence, creative direction, and UX-conscious design. Repositioning subtitles from a function of "translation" to a role of "cultural mediation" is essential for enhancing international recognition and appreciation.

As this study suggests, the rise of subtitle literacy is not a mere technological phenomenon but a social and cultural shift, reflecting transformations in language use, media consumption, and viewing practices. This perspective provides a valuable framework for future developments in audiovisual production, education, and media policy. The evolution of subtitled viewing habits and reception patterns offers a new lens for understanding the future of global audiovisual culture. Subtitles are no longer merely auxiliary features; in certain high-profile works, they function as integral expressive elements that support narrative and emotional delivery in the era of global media. Subtitles are no longer merely auxiliary features; in certain high-profile works, they function as integral expressive elements that support narrative and emotional delivery in the era of global media.

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Research Note

Blockchain Trust Infrastructure for Contract Management

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This research note explores blockchain's potential as trust infrastructure that enables sustainable value exchange through stakeholder-driven validation. Current blockchain applications often emphasize speculation over practical utility. Our approach eliminates speculative elements by limiting participation to contract stakeholders, achieving alignment of interests called the user-as-stakeholder. We implement this model through Proof of Authority consensus combined with custom staking mechanisms. Experimental results demonstrate that contract parties can effectively validate their own transactions while maintaining security and reducing intermediary dependence. This approach provides a foundation for blockchain's original vision as a "shared foundation for co-creative society," where participants act simultaneously as stakeholders and users of the infrastructure they maintain.

1. Blockchain Industry Issues and Need for Return to Origins

1.1 Current Dependency on Third-Party Validation

Digital contracts have become mainstream. Companies worldwide have moved from paper to digital systems. Yet something fundamental hasn't changed: we still ask third parties for permission to validate our own agreements.

The question is straightforward: when a freelancer and client agree on project milestones, why can't they verify completion themselves? Why must the people who care most about successful collaboration depend on platforms that profit from processing volume, not successful outcomes? This fundamental disconnect—between those with the strongest incentive for accuracy and those who actually perform validation—reveals the core problem with our current approach to digital trust.

The digital transformation wave has accelerated adoption of digital contract systems across industries, yet beneath this digital veneer, the fundamental structure remains unchanged: contract parties still depend on third-party intermediaries for validation and trust. We have digitized the process without addressing the core inefficiency.

1.2 The Blockchain Industry's Similar Mistake

The blockchain industry faces the same fundamental issue. As @ohmzeus points out in "Web3: Crypto's Biggest Mistake"[1], the industry has shifted toward speculation and away from solving real-world problems. The proliferation of complex protocols and unnecessary financialization represents self-indulgent technology rather than genuine innovation.

Social infrastructure should be simple, understandable, and robust. The most powerful technologies often appear deceptively simple because they solve fundamental problems without creating new ones. TCP/IP protocols that form the internet's foundation exemplify this principle—their simple, open design enabled countless innovative applications to flourish. Blockchain can achieve true value by removing excessive complexity rather than adding more layers of abstraction.

Current blockchain faces structural problems that mirror traditional systems: infrastructure centralization creates bottlenecks that contradict decentralization ideals, with transaction processing concentrated among specific operators in some Layer 2 and rollup solutions. Major networks prioritize token value over user needs, and persistent tension exists between trustless ideals and practical compliance requirements.

1.3 The user-as-stakeholder Solution

The answer lies in returning to blockchain's original purpose: creating a shared foundation where stakeholders validate their own transactions. This isn't about building more complex technology—it's about rebuilding trust through proper incentive alignment.

Our research demonstrates this return to origins through the user-as-stakeholder model, implemented via Proof of Authority (PoA) consensus[2]. This model addresses a fundamental question: why should we trust external validators when the people with the most at stake—the actual contract parties—have the strongest incentives for honest validation?

Traditional third-party models create a fundamental misalignment because validators profit from processing volume rather than outcome quality, while their economic incentives remain disconnected from user needs. These systems also create single points of failure with potential censorship risks, and their processes remain opaque with limited user control. In contrast, the User-As-Stakeholder solution ensures that validators bear direct consequences of contract outcomes, creating natural economic alignment with accuracy and fairness through distributed validation without central bottlenecks, while maintaining transparent and auditable processes with full user control.

Figure 1 illustrates the traditional approach where contract parties (User A, User B) must rely on centralized institutions such as banks, escrow services, and notaries for validation, creating bottlenecks and single points of failure. In contrast, Figure 2 demonstrates our proposed architecture where contract parties become their own validators (User A=Validator A, User B=Validator B) through PoA consensus with aligned economic incentives.

These architectural differences (Figures 1 and 2) illustrate how traditional systems create bottlenecks through mandatory third-party validation, while our system enables direct stakeholder validation with properly aligned incentives.

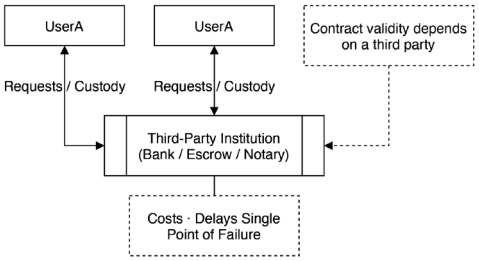

Figure 1: Traditional contract validation structure

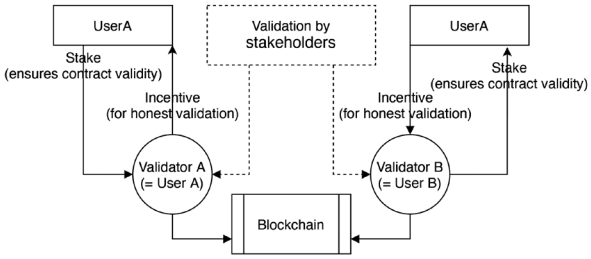

Figure 2: Proposed stakeholder-driven validation architecture

2. Technical Implementation and Results

2.1 Proof of Authority Architecture and Custom Staking

Our system implements this vision through Proof of Authority (PoA) consensus[2], which assigns validation rights to pre-approved stakeholders rather than anonymous miners. This approach provides three essential advantages. First, validators are known contract participants with reputational stakes, not anonymous entities optimizing for different goals. Second, the system requires no energy waste or speculative token economics, enabling straightforward validation by people who care about the outcomes. Third, it offers fast and predictable transaction processing without complex proof systems.

The fundamental difference lies in trust alignment. Instead of trusting unknown third parties, you trust the people who actually have direct stakes in successful outcomes. A freelancer and their client both want the contract to succeed and have every incentive to validate honestly, unlike traditional escrow services that profit regardless of contract success or failure.

2.2 Experimental Results and Validation

Our proof-of-concept experiments[4][5] demonstrated three critical capabilities that confirm the practical viability of stakeholder-driven validation.

The system proved its reliability and sustainability by successfully managing validator network changes without service interruption. Contract parties could join or leave the validation network seamlessly, demonstrating that the system maintains integrity even as its validator composition changes over time[4]. This addresses concerns about system availability and long-term operational stability.

Through custom smart contracts, the system demonstrated separation between consensus-layer validation and application-layer reward distribution. Stakeholders received validation rewards independent of the underlying PoA consensus mechanism, confirming the flexibility of the dual-layer architecture[4]. This separation allows for customized incentive structures tailored to specific business requirements.

The object-oriented smart contract design successfully created multiple contract instances from shared logic templates, demonstrating both code reusability and maintenance efficiency superior to monolithic approaches[4]. This modular architecture enables scalable deployment across different contract types and business contexts.

These results confirm that the approach is both technically sound and practically viable. Stakeholders can effectively validate their own transactions while maintaining system security and integrity. The system naturally prevents gaming because validators bear direct consequences of outcomes, eliminating the need for complex anti-fraud mechanisms.

2.3 Practical Application Example

Consider an international contract between a US client and Japanese developer. The traditional process requires multi-platform registration, cross-platform coordination, third-party authentication, complex escrow arrangements, and sequential approvals with potential delays at each stage. In contrast, the stakeholder-validated process enables direct contract creation on shared platform, permanent recording of terms and participants, and milestone-based validation without intermediary delays.

Figure 3 shows the traditional process requiring multi-platform registration, cross-platform coordination, third-party authentication, complex escrow arrangements, and sequential approvals with potential delays at each stage. In contrast, Figure 4 demonstrates our proposed approach where US clients and Japanese developers can create contracts directly on a shared platform and validate milestones without intermediary delays.

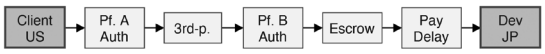

Figure 3: Traditional contract workflow for international freelance contracts

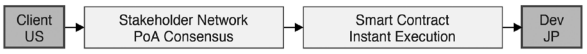

Figure 4: Proposed stakeholder validation workflow

This workflow comparison (Figures 3 and 4) illustrates how eliminating intermediary coordination reduces process complexity while maintaining security through stakeholder alignment and blockchain-based validation. This represents structural transformation that returns control to the people who actually care about the outcomes, rather than mere process optimization.

3. Toward Shared Foundation for Co-creative Society

3.1 Beyond Contract Management: Universal Application

The user-as-stakeholder model extends far beyond contract management. This approach applies wherever participants bear direct consequences of outcomes and can benefit from eliminating intermediary dependencies.

In supply chain verification, manufacturers, distributors, and retailers can validate product authenticity and compliance directly,

without relying on external certification bodies that may have different priorities. For professional services, lawyers, consultants, and clients can manage project deliverables and payments collaboratively, eliminating traditional billing disputes through transparent milestone validation. In international trade, exporters, importers, and logistics providers can coordinate complex multi-party transactions without traditional banking delays or excessive documentation requirements. For community governance, local stakeholder groups can manage shared resources through collective validation and decision-making processes, eliminating the need for external administrators.

When validators have direct stakes in successful outcomes, they naturally optimize for quality over quantity. This creates more reliable and efficient systems than traditional intermediary-based approaches, as validators' success directly depends on the success of the processes they validate.

3.2 The Vision: Shared Foundation for Co-creative Society

This approach represents more than technological innovation—it offers a pathway to genuine co-creative society. When stakeholders directly control validation of their own interactions, we eliminate the extractive intermediaries that currently profit from managing trust. Instead, trust becomes a shared resource maintained by those who benefit from its integrity.

The ultimate evolution envisions stakeholder communities forming Decentralized Autonomous Organization (DAO)[6] to govern validation processes collectively. This could fundamentally reshape how trust operates in digital commerce, moving away from dependency on extractive intermediaries toward systems where participants serve simultaneously as stakeholders and users.

3.3 Research Implications and Social Impact

Our proof-of-concept validates a core premise: contract parties can effectively validate their own transactions without sacrificing security[3][4][5]. This validation carries important implications for understanding how trust mechanisms can be restructured in digital systems.

The key insight is economic rather than technological: when validators are also contract beneficiaries, they optimize for successful outcomes rather than processing volume. This alignment creates natural incentives for accurate validation without requiring complex enforcement mechanisms.

This research demonstrates blockchain's potential to fulfill its foundational promise: enabling direct peer-to-peer collaboration without extractive intermediaries[3][4][5]. The significance lies not in technical innovation, but in social transformation—returning agency to the people who have the greatest stake in successful outcomes.

By proving that stakeholder-driven validation works in practice, this research challenges the assumption that trust requires neutral third parties. Instead, it suggests that the most trustworthy validators are often those with the most to gain from honest validation and the most to lose from failure. This insight has profound implications for how we design collaborative systems across industries and societies.

The success of such systems depends not on overcoming technical challenges, but on addressing institutional inertia that favors established intermediary systems. The path forward requires demonstrating practical value that stakeholders can directly experience, rather than promising theoretical benefits that may never materialize.

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Research Note

Jaw Motion Tracking in Unity using a monocular camera and ArUco markers

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This study developed a low-cost jaw movement tracking system using a monocular camera and planar markers (ArUco) with promote the widespread adoption of jaw movement analysis in dental clinical practice. The system was built on Unity 6 and OpenCV for Unity platforms, implementing algorithms for Perspective-n-Point (PnP) problem solving, three-dimentional rigid body fusion using the Kabsch method, and terminal hinge axis estimation through weighted least squares methods. Compared to existing expensive jaw movement measurement devices, this system can be configured using only general-purpose cameras and markers, enabling easy chairside utilization. This paper reports on the accuracy verification for clinical applications and discusses future prospects.

1. Introduction

1.1 Clinical Significance of Jaw Movement Measurement

Accurate recording and analyses of jaw movement are essential for successful prosthetic treatment. Particularly in full-mouth occlusal reconstruction and the diagnosis of temporomandibular disorders (TMD), understanding mandibular movement trajectories and centers of rotation serves as a crucial indicator for treatment planning decisions. However, in current clinical practice, jaw movement measurement using dedicated equipment is not positioned as a standard examination in the Diagnostic Criteria for Temporomandibular Disorders (DC/TMD)[1] or in the clinical guidelines of the Japanese Society for the Temporomandibular Joint[2]. The primary reasons for this are the high implementation costs of the existing systems, complex operational procedures, and difficulties in interpreting measurement results.

1.2 Historical Development of Jaw Movement Kinematics

Jaw movement fundamentally consists of two components: rotational and translational (sliding) movements. While anteroposterior movements (protrusive and retrusive movements) primarily involve only translational motion, opening and closing movements represent a complex combination of rotational and translational motions. Understanding these complex movement patterns has gradually deepened with the development of jaw movement kinematics.

In the early 20th century, the gnathology school founded by Dr. Beverly B. McCollum and Charles E. Stuart proposed the existence of a fixed rotational axis (terminal hinge axis) in mandibular movement. Posselt theorized that during the initial phase of the opening movement (approximately 20-25mm), the mandibular condyle performed purely rotational motion, with anterior translational movement being added only during subsequent opening phases[3]. This "initial rotation-later translation" two-stage theory became the theoretical foundation for the development of fully adjustable articulators and pantographs based on the hinge axis has served as a guideline for prosthetic treatment for many years.

Subsequently, Dr. Shoji Kohno from Japan proposed the concept of the "kinematic axis," which captured jaw movement more dynamically[4]. Dr. Kohno mathematically analyzed the trajectories of anterior-posterior and opening-closing movements, and deveroped methods to determine instantaneous centers of rotation. In this theory, the rotational axis of jaw movement was understood not as fixed, but as a dynamic axis that continuously changes according to movement.

Aprecise three-dimensional analysis using modern digital jaw movement measurement devices (CADIAX, JMA-Optic, etc.) has led to significant modifications to conventional theories. These high-precision measurements revealed that even during the initial phase of the opening movement, translational motion is present alongside rotational motion, albeit minimally, rather than pure rotational movement[5]. This demonstrated that the hypothesis of "initial purely hinge rotation" proposed by the gnathology school differs from actual biological movement.

Furthermore, detailed research on the instantaneous rotational axis of jaw movement has advanced in recent years. In 2023, Bescond et al. reported complete three-dimensional kinematic parameters of the temporomandibular joint using a novel method that fused MRI data with optical motion capture[6]. This study demonstrated through an instantaneous helical axis (IHA) analysis that the rotational axis is oriented obliquely during opening-closing movements and its position continuously changes during motion. Particularly interesting was the observation of asymmetric movement patterns between the left and right temporomandibular joints, with different movement trajectories on the working and balancing sides. These findings indicate the reality of more complex jaw movements that cannot be explained by conventional fixed-axis theories or simple dynamic axis models, suggesting the need for fundamental reconstruction of the jaw movement theory.

Based on this historical background and the latest findings, The present study aimed to simple and accurate a method for obtaining the terminal hinge axis from the perspective of clinical reproducibility. Specifically, the goal was to establish a practical approach applicable to clinical use while leveraging

the advantages of both conventional fixed-axis and dynamic-axis theories.

The current diagnosis of temporomandibular disorders is based on interviews, visual examination, palpation, and simple measurements of mouth opening range and lateral movement as indicated by DC/TMD and domestic guidelines, with jaw movement measurement using dedicated equipment not positioned as a standard examination. This is because interpretation of device measurements is difficult, and the diagnostic added value relative to cost and time is limited. However, if "simple and reproducible movement indicators" that can be used rapidly in clinical settings and intuitively communicate results to patients could be established, they would contribute to disease type stratification and objective evaluation of treatment efficacy, potentially becoming a powerful tool to reinforce the chairside diagnosis emphasized by the guidelines.

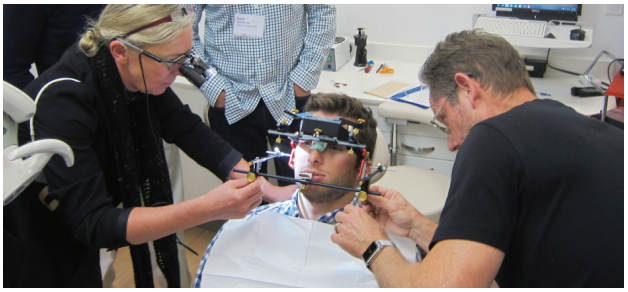

Figure1: CADIAX4: A Digital Jaw Movement Measurement Device as the Modern Version of the Pantograph

This system records mandibular movement trajectories with high precision using a digital recording plate mounted on the temporal region. The condylar movement pathway is back-calculated from stylus movements to identify the position of the terminal hinge axis. While this device can record motion in 6 degrees of freedom, the implementation cost exceeds 5 million yen.

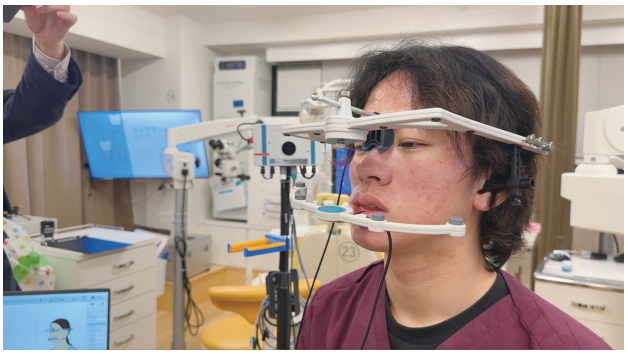

Figure 2: WinJMA

This system measures jaw position and orientation in a contactless manner using ultrasonic sensors. Eight sensors record motion in 6 degrees of freedom, enabling real-time three-dimensional display. Compared to magnetic systems, it has the advantage of being less susceptible to interference from metallic prostheses. The latest JMA-Optic model is not approved in Japan.

2. Related Work and Positioning

2.1 Classification of Existing Jaw Movement Measurement Systems

Table1 shows the major commercially available jaw movement measurement systems.While these systems enable high-precision measurements, they typically exceed 3 million yen in implementation cost, making introduction difficult for small-scale dental clinics.

Table 1: Comparison of jaw tracking systems

No.	Device Name	Manufacturer	Recording Method	Sensor Details	DOF	Contact Type
1	JMA-Optic	Zebris Medical GmbH	Optical	Digital camera ×2	6 DOF	Non-contact
2	ARCUSdigma 3	KaVo Dental	Ultrasonic	ultrasonic sensor x8	6 DOF	Non-contact
3	MM-J2	Shofu	Optical	LED + PSD sensor ×2	6 DOF	Non-contact
4	K7x	Myotronics	Magnetic	Magnetic sensor ×8	6 DOF	Non-contact
5	Modjaw	Modjaw	Optical	Digital camera ×2	4D tracking	Non-contact
6	e-Motion	SHINING 3D	Optical	Digital camera ×4	6 DOF	Non-contact
7	Cadiax 4	GAMMA Dental	Electronic	sensor flags ×2	6 DOF	Contact
8	**Present work**	-	Optical	ArUco ×6, solvePnP	6 DOF	Non-contact

2.2 Novelty and Clinical Significance of This Study

The system proposed in this study is differentiated from existing systems in the following aspects:

(1)**Low-cost implementation**: Composed only of a digital camera ZVE-10M2 (Sony Corporation, Tokyo, Japan) and ArUco markers (printing cost)

(2)**Open-source foundation**: Uses Unity 6 (Unity Technologies, San Francisco, USA) and OpenCV, enabling easy customization

(3)**Immediate chairside utilization**: Completion from calibration to measurement within 5 minutes

(4)**Visual feedback**: Enables use in patient education through 3D real-time display

3. Methods

3.1 System Configuration and Operating Environment

The basic configuration of this system is shown below:

(a)Camera: Sony ZV-E10M2 (Sony Corporation, Tokyo, Japan) (4K@30fps, via NVIDIA Broadcast (NVIDIA Corporation, Santa Clara, USA))

(b)Markers: ArUco dictionary DICT_4X4_50, edge length 10mm × 6 pieces

(c)Validation model: Dental cast mounted on Handy 2A average value articulator (Handy Dental Supply, Tokyo, Japan)

Software Environment

(a)Unity 6 (Unity Technologies, San Francisco, USA) (3D environment construction)

(b)OpenCV for Unity 3.0.0 (OpenCV.org, open-source project) (image processing and pose estimation)

(c)Modules used: Aruco, Calib3d, Imgproc

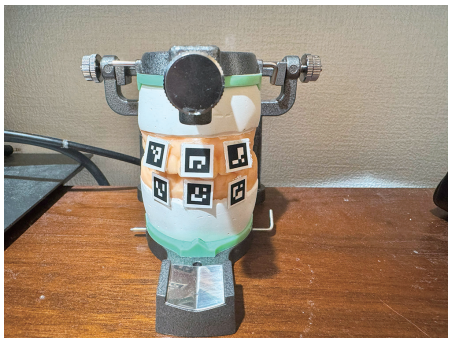

Figure 3: Marker Placement on Experimental Articulator

Three ArUco markers (ID 0-2) were placed on the maxillary section and three markers (ID 3-5) on the mandibular section of the Handy 2A average value articulator (Shofu Inc., Kyoto, Japan). The markers were fixed with strong adhesive to maintain a consistent positional relationship relative to the dental arch.

3.2 Camera Calibration and Coordinate System Transformation

3.2.1 Estimation of Intrinsic Parameters

Camera calibration is an important process for establishing the correspondence between 2-D image coordinates and 3-D world coordinates. In this system, using OpenCV's checkerboard detection function, the procedure is as follows:

Checkerboard specifications:

- Number of inner corner points: 10 × 7 (grid points)
- Square size: 25 mm
- Minimum required number of frames: 15

Figure4: Checker Board

During calibration, the Calib3d.findChessboardCorners function detects the corner points in each frame, and pairs of corresponding 3-D coordinates (given by the known checkerboard dimensions) and 2-D image coordinates are collected. Once 15 or more multi-view frames have been acquired, the camera intrinsic parameter matrix is estimated with Calib3d.calibrateCamera.

3.2.2 Implementation of Coordinate System Transformation

Because OpenCV and Unity define their coordinate systems differently, an appropriate transformation is required:

Table2: Axis Orientation in OpenCV and Unity Coordinate Systems

Axis	OpenCV (image coordinate convention)	Unity
X	Rightward	Rightward
Y	Downward (image coordinates)	Upward
Z	Forward from the camera	Forward

In the code implementation (ConvertToMatrix4x4 method), this coordinate system transformation is achieved by inverting the signs of the Y and Z components of the rotation matrix obtained via the Rodrigues formula: Y-axis inversion (OpenCV downward → Unity upward)

3.3 ArUco Marker Detection and Pose Estimation

3.3.1 Image Preprocessing Pipeline

To improve marker detection accuracy, the following preprocessing steps are applied:

(1)Grayscale conversion: convert RGBA color images to luminance images

(2)Bilateral filter: remove noise while preserving edges (d = 9, σ_color = 75, σ_space = 75)

(3)CLAHE (Contrast Limited Adaptive Histogram Equalization): local contrast enhancement (clipLimit = 2.0, tileGridSize = 8 × 8)

These preprocessing steps enable stable marker detection even under non-uniform illumination conditions.

3.3.2 6DoF Pose Estimation via the PnP Problem

For ArUco marker detection, the ArucoDetector class in OpenCV for Unity 3.0.0 is used. The detection process is as follows:

Marker detection:

Obtain the predefined ArUco dictionary DICT_4X4_50, combine it with the default DetectorParameters, and construct an ArucoDetector. Then call detectMarkers(grayMat, corners, ids) to detect ArUco markers in the input grayscale image grayMat, storing the four-corner coordinates of each marker in corners and the corresponding marker IDs in ids. Because these objects are created inside using blocks, they are automatically disposed when the block ends, releasing their native resources.

Pose estimation via a PnP solver:

For each detected marker, the rotation vector (rvec) and translation vector (tvec) are estimated by the solvePnP function from the 2D–3D correspondences of the four corner points. The 3D coordinate model of the marker is defined as a square with an edge length of 10 mm:

Outlier handling and smoothing:

If the difference in pose from the previous frame exceeds 90 degrees, it is discarded as an outlier, and the pose is smoothed by an exponential moving average (α = 0.2).

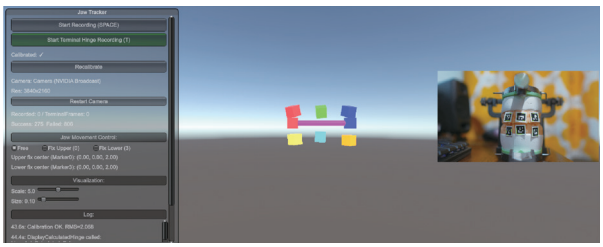

Figure 5: Unity runtime screenshot after camera calibration.

With the camera directed at the marker board, all six ArUco markers (IDs 0–5) are detected. For each marker, a color-coded sphere is rigidly attached to the estimated 6-DoF marker frame, so its position and orientation update in real time, demonstrating stable per-frame tracking. The left panel reports calibration status and runtime diagnostics, and the right inset shows the live camera feed.

3.4 Rigid Fusion via the Kabsch Method

3.4.1 Formulation of the Weighted Kabsch Method

The core technique of this system, the weighted Kabsch method, optimally aligns up to 12 corner 3D points obtained from multiple markers with a single rigid transformation. The minimization problem is formulated as follows:

$$\min_{R,t} \sum_{j=1}^{N} w_j \, \|Y_j - (RX_j + t)\|^2, \quad R^\top R = I, \ \det(R) = 1 \tag{1}$$

X_j: Template point in the jaw-local coordinate system (fixed in the initial frame)
Y_j: Observed point in the current frame (camera coordinates; metric units [m])
j >= 0: Confidence weight for point j (larger = more trusted)
N: Number of points used (up to 12 = 3 markers x 4 corners)
R: 3x3 rotation matrix (orthonormal; right-handed; det(R) = +1)
t: 3x1 translation vector

In short: Find R and t that move X_j to best match Y_j, minimizing the weighted sum of squared errors and using w_j as confidence weights.

3.4.2 Confidence Weight Computation

For each corner point, the weight w_j is computed dynamically based on the reprojection error:

$$w_j = \exp\left(-\frac{e_j^2}{2\kappa^2}\right) \tag{2}$$

where:
- e_j : reprojection error of corner j (in pixels)
- κ : scale parameter (default: 3 pixels)

This weighting function automatically down-weights corners with large reprojection errors (e.g., low detection accuracy or partial occlusion).

3.4.3 Algorithm for Solving the Kabsch Method

In implementation, the optimal rigid transformation is obtained by the following steps:

(a) Compute the weighted centroids:

$$\bar{\mathbf{X}} = \frac{\sum_{j=1}^{N} w_j \mathbf{X}_j}{\sum_{j=1}^{N} w_j}, \qquad \bar{\mathbf{Y}} = \frac{\sum_{j=1}^{N} w_j \mathbf{Y}_j}{\sum_{j=1}^{N} w_j} \tag{3}$$

Compute the weighted centroids of the template and observed points to remove global translation and reflect each point's confidence.

(b) Build the cross-covariance matrix:

$$\mathbf{H} = \sum_{j=1}^{N} w_j \, (\mathbf{X}_j - \bar{\mathbf{X}}) \, (\mathbf{Y}_j - \bar{\mathbf{Y}})^\top \tag{4}$$

Center both point sets and build the weighted cross-covariance matrix, which captures how their coordinates vary together under the optimal rotation.

(c) Perform singular value decomposition (SVD):

$$\mathbf{H} = \mathbf{U} \mathbf{\Sigma} \mathbf{V}^\top \tag{5}$$

Perform SVD on the cross-covariance to extract orthonormal bases whose alignment yields the least-squares rotation.

(d) Compute the optimal rotation matrix:

$$\mathbf{R} = \mathbf{V} \, \mathrm{diag}\big(1, \ 1, \ \mathrm{sign}(\det(\mathbf{V}\mathbf{U}^\top))\big) \, \mathbf{U}^\top \tag{6}$$

Construct the rotation, enforcing a proper rotation (detRRR=+1) and rejecting reflections.The determinant term ensures a proper rotation (i.e., no reflection).

(e) Compute the optimal translation vector:

$$\mathbf{t} = \bar{\mathbf{Y}} - \mathbf{R} \, \bar{\mathbf{X}} \tag{7}$$

Recover the translation by aligning centroids—set ttt so the rotated template centroid coincides with the observed centroid.

3.5 Recording Mode and Quality Control

3.5.1 Template Fixation and Monotonic Motion

At the start of recording (key **T**), in the first **complete frame** (all six markers detected), the corner 3D template points Xj for the maxilla and mandible are fixed in each jaw's local coordinate system. This design enables:

(a)Consistent rigid alignment against the same reference in all subsequent frames

(b)Robustness to partial marker dropouts (operates with at least three markers)

(c)Improved measurement repeatability

Motion is restricted to **monotonic opening or closing**. This ensures:

(d)Consistent screw-axis direction

(e)Avoidance of numerical instabilities

(f)Short acquisition time (10–15 seconds)

3.5.2 Quantifying Frame Quality

For each frame, define a quality score

$$\omega_i \in [0, 1] \tag{8}$$

computed from the mean reprojection error:

$$\omega_i = \exp\left(-\frac{\bar{e}_i^2}{2\kappa^2}\right) \tag{9}$$

where $\bar{e}_i$ is the mean reprojection error of all corners in frame i.

3.6 Screw-Axis Estimation Algorithm

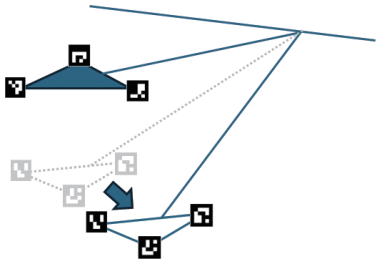

Figure6: Schematic of screw-axis estimation from fused upper/ lower corner sets (12 + 12 points)

Corner points (up to 12 per jaw) are rigidly fused (Kabsch) into maxillary and mandibular frames. The frames' relative motion yields per-frame axis directions, which are sign-aligned and weighted by rotation magnitude and frame quality to obtain a single global axis. A representative point on the axis is then estimated, and left/right hinge points are placed using the known intercondylar distance. Monotonic opening/closing preserves a consistent axis orientation.

3.6.1 Relative Transform and Axis–Angle Representation

For each frame iii, the maxilla–mandible relative transform is

$$\mathbf{T}_{\mathrm{rel},\,i} = \mathbf{U}_i^{-1}\,\mathbf{L}_i \tag{10}$$

Where U_i is the maxillary frame and L_i is the mandibular frame (both are outputs of the Kabsch step).

Decompose each relative transform into an axis–angle representation:

(a)Axis direction: w_i (unit vector)

(b)Rotation angle: θ_i (radians)

3.6.2 Weighted Axis Direction Estimation

The axis direction is estimated by a weighted average using the rotation angle and frame quality:

Figure 6. Weighted estimation of the axis direction

$$\hat{w} = \frac{\left|\sum_{i=1}^{M} s_i\,\theta_i\,\omega_i\,w_i\right|}{\sum_{i=1}^{M} s_i\,\theta_i\,\omega_i\,w_i} \tag{11}$$

where

(a) $s_i \in \{+1, -1\}$: sign-consistency factor (aligned with the frame having the maximum rotation angle),

(b)θ_i: rotation angle of frame iii,

(c)ω_i: frame quality,

(d)M: total number of frames.

This weighting scheme:

(e)increases the contribution of frames with larger rotation angles,

(f)automatically suppresses low-quality frames,

(g)improves robustness against outliers.

3.6.3 Least-Squares Estimation of a Representative Point on the Axis

Linear approximation of the screw motion:

$$\mathbf{t}_{\mathrm{rel},\,i} = \left(\mathbf{I} - \mathbf{R}_{\mathrm{rel},\,i}\right)\mathbf{q} \tag{12}$$

where q is a representative point on the axis.

Stack all frames with quality weights:

$$\begin{bmatrix} \sqrt{\omega_1}\,(\mathbf{I} - \mathbf{R}_{\mathrm{rel},\,1}) \\ \sqrt{\omega_2}\,(\mathbf{I} - \mathbf{R}_{\mathrm{rel},\,2}) \\ \vdots \\ \sqrt{\omega_M}\,(\mathbf{I} - \mathbf{R}_{\mathrm{rel},\,M}) \end{bmatrix} \mathbf{q} = \begin{bmatrix} \sqrt{\omega_1}\,\mathbf{t}_{\mathrm{rel},\,1} \\ \sqrt{\omega_2}\,\mathbf{t}_{\mathrm{rel},\,2} \\ \vdots \\ \sqrt{\omega_M}\,\mathbf{t}_{\mathrm{rel},\,M} \end{bmatrix} \tag{13}$$

Solve this overdetermined system via SVD to obtain the least-squares solution $\hat{q}$.

3.7 Placement and Validation of Hinge Points

3.7.1 Determination of Left and Right Hinge Points

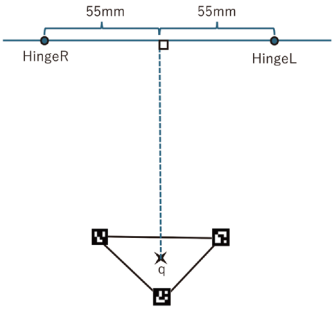

Figure 7: Hinge-center selection and placement of left/right hinge points

After the global screw axis is estimated, the mandibular centroid is projected perpendicularly onto the axis. The foot of this perpendicular defines the hinge center. The left (L) and right (R) hinge points are then placed by translating from the hinge center along the axis in opposite directions by half of the known intercondylar distance. The mandibular markers illustrate how the centroid is obtained; the axis orientation is used to assign L/R consistently in the mandibular local coordinate system.

The representative point $\hat{q}$

on the screw axis is determined by least squares as the point on the axis that minimizes the perpendicular distance from the mandibular centroid. This point corresponds to the midpoint between the condyles and provides the most stable estimate of the mandibular center of rotation.

From $\hat{q}$, place the left and right hinge points using the known intercondylar distance W (default: 110 mm):

$$\mathbf{q}_R = \hat{\mathbf{q}} - \frac{w}{2}\,\hat{\mathbf{w}}, \qquad \mathbf{q}_L = \hat{\mathbf{q}} + \frac{w}{2}\,\hat{\mathbf{w}} \tag{14}$$

where q_R is the right hinge point (patient's right condyle), q_L is the left hinge point (patient's left condyle), and $\hat{w}$ is the normalized screw-axis direction vector.

The left/right assignment is decided by the sign of $\hat{w} \cdot x$ in the mandibular local coordinate system: a positive value indicates the axis points toward the patient's left; a negative value indicates it points toward the patient's right.

3.7.2 Saving to the Local Coordinate System

Store the estimated screw axis in the mandibular local coordinate system as follows:

(a)Convert the hinge-axis center point from world/camera space into mandibular local space by applying the inverse of the current mandibular pose (transform).

(b)Convert the hinge-axis direction vector in the same way, then normalize it to maintain unit length.

Persist the screw axis by saving these two local quantities—the local center and the local direction—as the canonical local representation used for subsequent reconstruction.

With the axis saved in mandibular local coordinates, you can reconstruct its world/camera-space position and direction at any later frame by applying the current mandibular pose to the stored local center and direction. This allows robust recovery of the axis even when some markers are temporarily not detected, since reconstruction depends only on the current mandibular pose and the saved local representation.

3.8 Diagnostic Check of Arc Validity

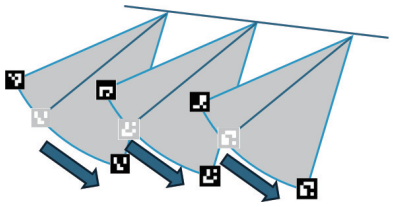

Figure 8: Pairwise arc-based validation of the screw axis.

During the validation step, each maxilla–mandible marker pair is examined under a pure hinge assumption. Their trajectories are projected onto the plane orthogonal to the candidate axis, where they should form circular arcs with a common center aligned with the axis. The figure illustrates successive frames for multiple pairs (arrows indicate motion). Consistency of arc centers and radii across pairs supports the estimated screw axis, whereas systematic offsets reveal axis misalignment. These discrepancies are summarized by the validity metrics reported in Section 3.8.2.

3.8.1 Circle Fitting by the Kåsa Method

Project the trajectories of the mandibular markers (IDs 3, 4, 5) onto the plane orthogonal to the estimated axis, and perform **algebraic circle fitting**:

$$\min_{a,b,c} \sum_{i=1}^{n} \left(x_i^2 + y_i^2 + a\,x_i + b\,y_i + c\right)^2 \tag{15}$$

Circle parameters:

(a)Center: $(-a/2, -b/2)$

(b)Radius:

$$\sqrt{\frac{a^2}{4} + \frac{b^2}{4} - c} \tag{16}$$

(Also known as the Kasa method.)

3.8.2 Validity Metrics

Quantify the validity of the estimated axis using the following metrics:

(a)**RMS residual**: root-mean-square error from the fitted circle.

(b)**Coefficient of variation (CV) of radius**: temporal consistency of the radius.

(c)**Axis distance**: distance from the circle center to the estimated axis (ideally 0).

(d)**Plane thickness**: standard deviation of axial offsets before projection.

Additionally, fit a **total least squares (TLS)** line to **the three circle centers** (from markers 3, 4, 5) and verify that its direction agrees with $\hat{\mathcal{W}}$ to further validate the estimate.

3.9 Separation of Numerical Computation and Visualization

This system strictly separates **numerical computation (Math)** from **visualization (Render)**:

Numerics layer (Math):

(a)All geometric computations use metric units [m][m][m].

(b)Processing is unified in the **camera coordinate system**.

(c)Floating-point precision is utilized to the fullest.

Visualization layer (Render):

(d)Apply a **display scale** (VIS_SCALE).

(e)Add a **Z-axis offset** for visibility.

(f)Place visual elements as **children of the camera**.

The unidirectional data flow (Math → Render) ensures that:

(g)Numerical consistency and reproducibility are ensured.

(h)Changes to visualization parameters do **not** affect computed results.

(i)Debugging and validation are simplified.

4. Results

4.1 System Functionality Check

We implemented the system in a Unity 6 environment and measured jaw motion using a dental arch model mounted on a Handy 2A average-value articulator. With a Sony ZV-E10M2 camera (via NVIDIA Broadcast at 4K@30fps), we confirmed real-time detection and tracking of six ArUco markers (DICT_4X4_50; side length 10 mm).

4.2 Calibration and Pose-Estimation Stability

Camera calibration using a checkerboard (10x7 inner corners, 25 mm squares) was performed by automatically collecting 15 frames. In per-marker solvePnP pose estimation, outliers were rejected when the inter-frame orientation change exceeded 90 degrees, and smoothing with an exponential moving average (alpha = 0.2) was confirmed to be effective.

4.3 Jaw-Frame Estimation via Kabsch Fusion

Using 3D–3D rigid least squares (the Kabsch method), we implemented generation of a unified jaw frame (maxilla and mandible) from up to 12 corner points across multiple markers. Reprojection-error weighting (kappa = 3 px) was incorporated, and jaw-frame estimation was confirmed to execute in frames where all six markers were detected.

4.4 Terminal Hinge-Axis Estimation

From recordings of monotonic opening/closing motion, we implemented the following pipeline:

(a)Compute the axis direction ($\hat{\mathcal{W}}$) from relative transforms using a rotation-angle × quality weighted average.
(b)Estimate a representative point q on the axis via a linearized screw-motion model using least squares.
(c)Place left/right hinge points using the known intercondylar distance (110 mm).
These processes run continuously, and the estimated hinge axis is visualized in 3D within the Unity scene.

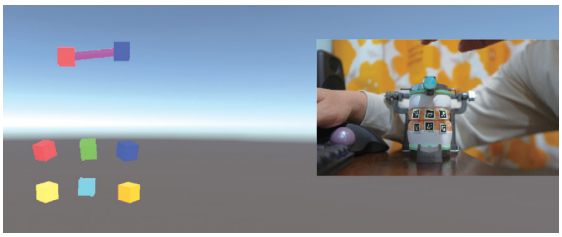

Figure 9: Real-time visualization of the estimated screw axis and left/right hinge points

Unity runtime view showing the screw axis and the right/left hinge points rendered together with the marker-attached reference cubes. As the ArUco marker poses change, the estimated axis and hinge points update frame-by-frame, demonstrating stable closed-loop tracking. The inset shows the live camera feed; the colored cubes correspond to the individual marker frames used for fusion.

4.5 Arc-Validity Diagnostics

We implemented a diagnostic that projects the trajectories of mandibular markers (IDs 3, 4, 5) onto the plane orthogonal to the axis and performs circle fitting using the Kasa method. The following metrics were computed and displayed:
(a)RMS residual of the circle fit
(b)Coefficient of variation (CV) of the radius
(c)Distance from the fitted circle center to the estimated axis
(d)Variance of axial offsets (thickness) prior to projection

5. Novelty of This Study

5.1 Technical Novelty

Realization with a single monocular camera.
Unlike existing commercial systems (e.g., Zebris, Modjaw) that require multiple cameras or dedicated hardware, our method achieves jaw-motion measurement and hinge-axis estimation using only a general-purpose monocular camera and six ArUco markers. This can potentially reduce equipment cost to less than one-tenth of existing solutions.
Applying Kabsch-based rigid fusion to jaw-motion estimation.
We estimate a jaw frame by simultaneously aligning up to 12 marker corner points with a single rigid transform using the Kabsch method. This differs from simple averaging of per-marker poses or three-point methods and provides a statistically optimal rigid pose. Reprojection-error-based weighting improves robustness to noise and outliers.
Weighted least-squares screw-axis estimation.
By considering both frame quality (ωi) and rotation angle (Θi), the proposed weighted estimation naturally down-weights low-quality or small-angle frames. Under the monotonic-motion constraint, this enables axis estimation with a limited number of frames.

5.2 Implementation Novelty

Integrated implementation in Unity.
Combining Unity 6 with OpenCV for Unity integrates real-time processing and 3D visualization. A one-way separation of numerical computation (Math) and visualization (Render) achieves both reproducibility of calculations and flexibility in display.
Use of an open-source technology stack.
By combining accessible components—ArUco (open-source marker system), OpenCV (image processing), and Unity (3D environment)—the system can be customized and extended by researchers and clinicians.

5.3 Clinical Novelty

Chairside readiness.
The setup is simple, and calibration-to-measurement can be completed quickly. Results can potentially be presented intuitively to patients via 3D visualization.
Design emphasizing reproducibility.
Choices such as monotonic motion, template fixation, and using only the Kabsch output improve measurement reproducibility, enabling longitudinal evaluations and inter-operator comparisons.
Path for incremental accuracy improvements.
The base system can be introduced at low cost, with accuracy improved stepwise by upgrading the camera, increasing the number of markers, or refining algorithms—contrasting with the all-at-once investment required by dedicated systems.

6. Discussion and Future Extensions

Weight design can be extended from a simple reprojection-error function to a hybrid scheme incorporating edge contrast and detector confidence. Introducing explicit outlier removal (thresholding angle/position residuals to exclude bad corners, followed by 1–2 refits) would increase robustness. When environmental changes occur (camera motion or fixture shift), allowing template re-anchoring enables stable long-duration recording. Accurate camera intrinsics (K, D) and marker size are essential; utilities for recalibration and size verification are desirable. The approach remains valid in monocular settings as long as marker dimensions are known and calibration is sufficient. By combining batch rigid alignment of corner points via Kabsch and angle × quality weighting for screw-axis estimation, stable recovery of jaw frames and the principal rotation axis is possible even with a small number of markers. Next steps include comparison against optical references and clinical datasets to quantify error characteristics, improve robustness, and refine UI/UX, as well as exploring integration with intraoral scan data and CBCT scans for enhanced visualization.

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Research Note

Shared Leadership Research from Traditional Teams to Virtual Collaborative Environments

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Shared leadership research has primarily focused on face-to-face teams, with limited exploration of virtual environments. This research note examines virtual teams and MMOGs as contexts for collaborative leadership research, reviewing developments through 2024.with emphasis on post-pandemic research. By bridging conventional management research with emerging virtual environment studies, this study presents future research agendas for understanding distributed leadership in digital-age collaborative contexts. The review revealed that shared leadership dynamics in virtual corporate teams and gaming environments offer unique insights into leadership emergence patterns and organizational effectiveness beyond traditional settings. Post-pandemic research particularly demonstrates the increased importance of shared leadership in online environments.

1. Introduction

1.1 Background and Problem Statement

Shared leadership, defined as a dynamic process whereby leadership roles are distributed among team members rather than concentrated in a single individual, has gained attention as an important organizational phenomenon. According to Pearce & Conger (2003), traditional research has primarily focused on co-located teams in conventional organizational settings[1]. However, rapid digitalization and the proliferation of virtual collaborative platforms have created new contexts for understanding distributed leadership phenomena.

Remote work and online communities present unique challenges and opportunities for shared leadership theory. As Avolio et al. (2014) point out, two distinct virtual environments deserve attention: corporate virtual teams and Massively Multiplayer Online Games (MMOGs), both demonstrating complex collaborative dynamics worthy of systematic investigation[2].

1.2 Research Objectives

This research note reviews shared leadership development and its application to virtual environments. High-quality literature was collected primarily from tier 1 and tier 2 peer-reviewed academic journals, supplemented by relevant conference proceedings from major databases. The review encompassed foundational theoretical research through the most recent studies (up to 2024), with particular emphasis on post-pandemic research since 2020.

The examination targeted literature from leading journals including Leadership Quarterly, Journal of Applied Psychology, Academy of Management Journal, Group & Organization Management, Human Resource Management Review, European Journal of Work and Organizational Psychology, Harvard Business Review, and Heliyon, complemented by proceedings from SIGCHI Conference on Human Factors in Computing Systems and Association of Industrial/Organizational Psychology conferences.

The scope of investigation included theoretical developments in shared leadership, empirical studies in corporate virtual teams and MMOG environments, and implications for future research. The analysis adopted an interdisciplinary perspective spanning organizational psychology, management science, and information systems to deepen understanding of leadership phenomena in virtual collaborative environments.

The central research question guiding this review is: How can insights from virtual collaborative environments—both corporate virtual teams and MMOGs—inform the development of shared leadership theory and practice in post-pandemic digital workplaces? This question is addressed through three specific objectives: (1) synthesizing theoretical developments in shared leadership with emphasis on virtual contexts, (2) comparing leadership dynamics across corporate and gaming environments to identify transferable insights, and (3) proposing an integrated research agenda for future investigations.

2. Literature Review of Shared Leadership Development

2.1 Traditional Shared Leadership Theory

The conceptual foundation of shared leadership was established through pioneering research challenging traditional hierarchical leadership models. Pearce & Conger (2003) provided an initial theoretical framework emphasizing shared leadership as an emergent and collective process, particularly in knowledge-intensive teams[3]. Empirical research by Pearce & Sims (2002) demonstrated the superior predictive validity of shared leadership compared to vertical leadership in organizational change contexts[4].

Carson, Tesluk, & Marrone (2007) significantly advanced shared leadership research by introducing a social network theory-based measurement approach using "density" to better capture the distribution of leadership influence among team members. Their partial cross-sectional study identified two key antecedent conditions for shared leadership emergence: an internal team environment (comprising shared purpose, social support, and voice) and external coaching. The study also revealed that external coaching is particularly crucial for shared leadership development when the internal team environment is unsupportive[5].

2.2 Digital Environment Transition and Post-Pandemic Developments

Meta-analytical evidence consistently supports shared leadership effectiveness across diverse organizational contexts. Wang, Waldman, & Zhang (2014) demonstrated an overall correlation of $\rho = .34$ between shared leadership and team effectiveness[6].

However, these foundational studies primarily focused on co-located teams. Since 2020, research on leadership in virtual environments has accelerated due to pandemic-driven workplace transformations. Tang et al. (2024) conducted research on 107 knowledge-based teams, revealing that shared leadership positively influences team innovation through team member exchange (TMX) and team resilience[7].

3. Virtual Collaborative Environments as Research Contexts

3.1 Corporate Virtual Teams

The conceptualization of e-leadership by Avolio, Kahai, & Dodge (2001), defined as leadership influence exercised through advanced information technology, represented significant theoretical progress[8]. This framework emphasized unique challenges in virtual team contexts, including trust building, communication effectiveness, and cultural integration.

Empirical research has demonstrated that shared leadership principles can be effectively applied to virtual corporate settings. Powell, Piccoli, & Ives (2004) found that shared leadership combined with robust structural support better predicts virtual team performance than traditional hierarchical approaches[9]. Purvanova & Bono (2009) established that transformational e-leadership behaviors enhance virtual team cohesion across national boundaries[10].

Post-pandemic research has further clarified the importance of leadership in virtual environments. Hertel (2024) revealed predominantly positive correlations between task-oriented, relational-oriented, and transformational leadership and follower responses in highly virtual contexts[11].

3.2 Online Gaming Environments

Online gaming environments, particularly MMOGs, represent unique laboratories for studying emergent leadership processes. Unlike traditional organizational settings with formal hierarchies, MMOGs provide spontaneous contexts where leadership emerges organically based on competence and contribution to collective goals.

Reeves et al. (2008) analyzed leadership emergence in EverQuest guilds, demonstrating that leadership surfaces through social influence and reputation dynamics parallel to shared leadership processes in organizational teams[12]. Gaming contexts offer advantages for leadership research: behaviors can be objectively observed through digital traces, high-stakes activities reveal authentic leadership behaviors, and voluntary participation ensures that influence is based on genuine effectiveness.

Driskell, Radtke, & Salas (2003) found that rotating leadership roles and shared decision-making improved coordination in complex collaborative tasks within virtual team environments[13]. Williams, Ducheneaut, & Xiong (2006) documented emergent directive leadership at critical moments complemented by collaborative strategic sessions in online gaming contexts[14].

Recent research by Mysirlaki & Paraskeva (2020) surveyed 500 MMOG players to examine the impact of leader emotional intelligence and transformational leadership on virtual team effectiveness[15]. Their findings revealed that emotional intelligence affects team effectiveness through transformational leadership behaviors.

3.3 Comparative Analysis

Virtual corporate teams and MMOGs share fundamental characteristics: distributed member locations, technology-mediated communication, task interdependence, and performance accountability. However, they differ significantly in formal structure, member motivation, and outcome consequences.

Corporate virtual teams operate within established organizational frameworks with external performance pressures, while MMOG

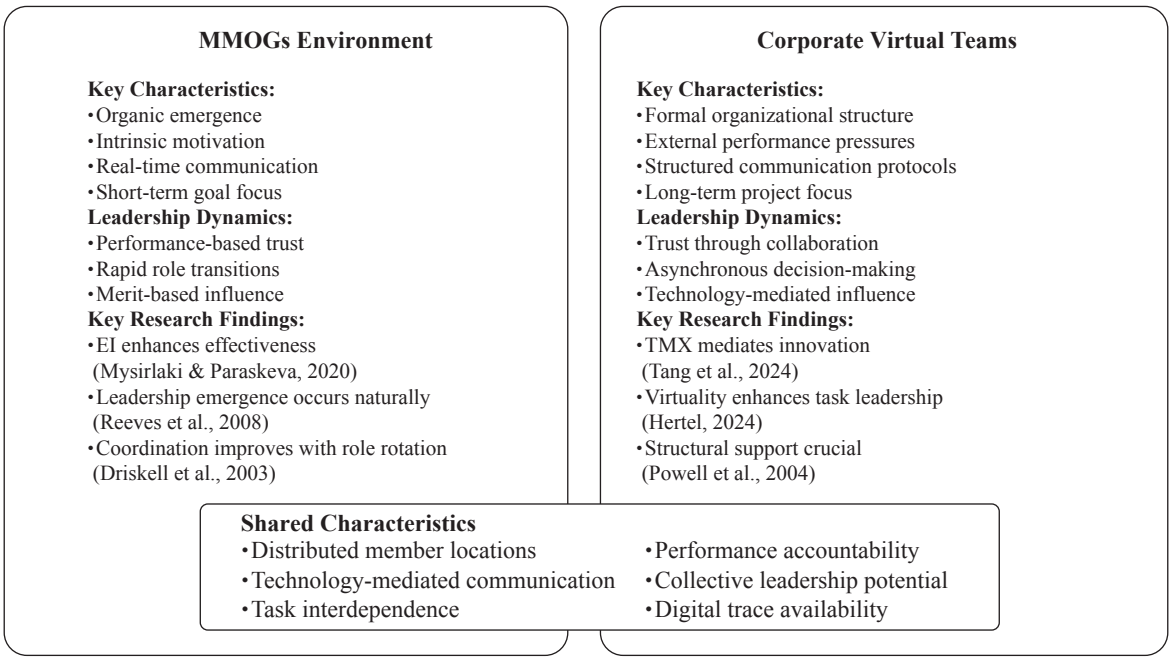

Figure1: Virtual Collaborative Environments for Shared Leadership Research

Table1: Integrated Future Research Agenda for Shared Leadership in Virtual Environments

Research Domain	Current Gaps	Proposed Research Directions	Key Methodological Approaches	Expected Outcomes
Theoretical Framework Development				
Post-pandemic hybrid work models	Limited integration of formal hierarchy and emergent leadership	- Develop hybrid leadership emergence models	- Longitudinal case studies	- Integrated theoretical frameworks
		- Investigate technology-mediated authority dynamics	- Mixed-methods designs	- Boundary condition specifications
		- Examine temporal leadership transitions	- Cross-cultural comparative analysis	- Cultural adaptation models
Mediation mechanisms	Incomplete understanding of TMX and resilience pathways	- Chain mediation model validation	- Structural equation modeling	- Process models refinement
		- Alternative mediating variables identification	- Multi-level analysis	- Moderator identification
		- Cultural moderator investigation	- Meta-analytic synthesis	- Cross-context validation
Methodological Innovations				
Digital trace analysis	Under-utilized rich behavioral data	- Natural language processing of team communications	- Big data analytics	- Behavioral prediction models
		- Network analysis of influence patterns	- AI-powered content analysis	- Objective leadership measures
		- Machine learning pattern recognition	- Real-time monitoring systems	- Intervention timing optimization
Real-time assessment	Lack of continuous measurement tools	- Pulse survey technologies development	- Mobile sensing technologies	- Just-in-time interventions
		- Digital dashboard systems	- Wearable device integration	- Performance optimization
		- AI-powered coaching systems	- Automated feedback systems	- Early warning systems
Practical Applications				
Organizational design	Misalignment with virtual leadership needs	- Flexible structure frameworks	- Design science research	- Organizational design guidelines
		- Communication protocol optimization	- Action research approaches	- Implementation roadmaps
		- Performance evaluation system redesign	- Pilot program evaluations	- ROI measurement tools
Leadership development	Traditional programs inadequate for virtual contexts	- Gamification strategy integration	- Experimental training designs	- Virtual leadership curricula
		- Cross-cultural competency programs	- Skill transfer assessment	- Training effectiveness metrics
		- Digital communication skill training	- Long-term impact evaluation	- Skill certification frameworks
Technology enhancement	Limited shared leadership support features	- Gaming-inspired platform features	- User experience research	- Enhanced collaboration tools
		- AI-powered role distribution systems	- Technology acceptance studies	- Feature implementation guides
		- VR/AR collaboration environments	- Platform effectiveness testing	- User adoption strategies
Research Priorities				
1. High Priority: Post-pandemic hybrid models, digital trace analysis, organizational design **2. Medium Priority**: Mediation mechanisms, real-time assessment, technology enhancement **3. Long-term Focus**: Cultural adaptation, VR/AR integration, AI-powered systems				
Cross-cutting Considerations				
Ethical Framework: Privacy protection, informed consent, data security **Industry Variation**: Technology, healthcare, finance, education sectors **Team Diversity**: Cultural, generational, skill-based differences **Technology Evolution**: Emerging platforms, AI advancement, connectivity improvements				

teams emerge organically around intrinsic motivation and voluntary participation[16]. These contextual differences provide opportunities for understanding boundary conditions of shared leadership effectiveness across varied virtual collaborative settings.

Figure 1 illustrates the commonalities and differences between corporate virtual teams and MMOG environments. Both environments share characteristics such as distributed member locations, technology-mediated communication, and task interdependence, but differ significantly in organizational structure and motivational factors. Corporate environments are characterized by formal organizational structure and external performance pressures, while MMOG environments feature organic emergence and intrinsic motivation that shape leadership dynamics. The central arrows represent the potential for mutual learning between the two environments, showing possibilities for rapid decision-making and crisis management skills developed in gaming contexts to transfer to corporate settings, and for structural support methods from corporate environments to contribute to the long-term sustainability of gaming communities.

Building on Fukunaga's (2024) initial research identifying key gaming leadership behaviors such as concise communication, broad perspective, and immediate feedback, this research extends these findings by examining the mediating mechanisms and contextual factors that influence their effectiveness[17]. While Fukunaga's research primarily focused on identifying effective behaviors through interviews, this study provides deeper analysis of how these behaviors operate differently in gaming versus corporate contexts, particularly regarding trust-building processes and temporal dynamics.

Chamberlin et al. (2024) identified that shared leadership manifests in collective configurations (where members share all leadership roles) and distributed configurations (where members assume specific roles)[18]. Collective configurations demonstrate higher team effectiveness through improved teamwork processes, particularly under high temporal dispersion conditions

3.4 Critical Gaps and Theoretical Tensions

Despite growing research interest, significant theoretical tensions remain unresolved. A critical gap exists in understanding

the temporal dynamics of shared leadership emergence: while Chamberlin et al. (2024) identified collective and distributed configurations[18], the mechanisms driving transitions between these configurations remain unclear. This is particularly problematic in virtual environments where leadership patterns may shift more rapidly than in traditional settings.

Another unresolved tension concerns the relationship between formal authority and emergent influence in virtual teams. Tang et al. (2024) demonstrated positive effects of shared leadership on innovation[7], yet their research, like most existing studies, does not adequately address how formal hierarchies should be structured to optimize rather than constrain emergent leadership. The gaming literature suggests that minimal formal structure facilitates organic leadership emergence[12][14], while corporate research emphasizes the need for structural support[9]. These contradictory findings suggest that boundary conditions—such as task complexity, team maturity, or cultural context—may moderate the effectiveness of different structural approaches, yet systematic investigation of these moderators is lacking.

These unresolved tensions suggest several priority research questions: (1) What triggers transitions between collective and distributed leadership configurations in virtual teams? (2) How do formal authority structures interact with emergent influence patterns across different task types? (3) What cultural and organizational factors moderate the effectiveness of minimal versus structured approaches to shared leadership development?

4. Future Research Agenda

4.1 Theoretical Framework Development

Current shared leadership theory requires expansion to address post-pandemic hybrid work environment characteristics. Future research should develop integrated theoretical frameworks that account for technology-mediated effects, asynchronous communication patterns, and distributed cognitive processes unique to virtual collaboration.

Development should draw from multiple theoretical traditions: media richness theory to understand how communication technologies enable or constrain shared leadership behaviors, social network theory for insights into influence flows through virtual team networks, and complexity theory to explain how shared leadership emerges as a collective property of virtual systems.

Particularly needed is theoretical research addressing the interaction between formal organizational hierarchies and emergent shared leadership in hybrid virtual-physical work environments. Tang et al. (2024) demonstrated that team member exchange and psychological resilience function as important mediating factors, suggesting that theoretical models must account for both relationship quality and collective capacity for adaptation[7].

4.2 Methodological Considerations

Virtual environments present opportunities for methodological innovation in shared leadership research. Digital communication platforms generate rich behavioral data that enable novel measurement approaches through network analysis, communication pattern recognition, and longitudinal tracking of leadership role transitions.

Network analysis techniques can reveal the structure and dynamics of influence relationships in virtual teams. Natural language processing can analyze team communication content and sentiment to identify leadership behaviors and their effects. Machine learning approaches can identify patterns in large datasets, potentially revealing leadership effectiveness factors undetectable through traditional methods.

The digital nature of virtual collaboration enables real-time assessment of team dynamics and leadership effectiveness. Future research should develop continuous monitoring methods for shared leadership behaviors, creating opportunities for timely intervention and support.

4.3 Practical Implications and Applications

Understanding shared leadership in virtual environments has immediate practical relevance for modern organizations undergoing digital transformation. Organizations should consider how their formal structures enable or constrain the emergence of shared leadership in virtual environments, including examination of reporting relationships, decision-making authority, and communication protocols.

Leadership development programs must evolve to address virtual and hybrid work environments. These programs should focus on developing digital communication skills, intercultural competencies, technological fluency, and the ability to build trust and relationships in virtual environments. Gamification strategies offer promising approaches that can make leadership development more engaging and effective through elements such as progressive skill building, immediate feedback, and collaborative challenges.

The gaming research stream offers particular potential for identifying technological features that enhance shared leadership emergence in organizational virtual teams. Empirical evidence supports this transfer: Reeves et al. (2008) demonstrated that guild leadership patterns in EverQuest parallel effective organizational team behaviors, particularly in rapid decision-making contexts[12]. Furthermore, Mysirlaki & Paraskeva (2020) found that emotional intelligence development through gaming leadership experiences transfers to transformational leadership effectiveness in professional settings[15]. Features such as real-time performance dashboards, collaborative decision-making tools, and reputation systems from gaming environments have shown promise when adapted for organizational use, as evidenced by the increasing adoption of gamification in corporate learning platforms.

Table 1 comprehensively presents the future agenda for shared leadership research in virtual environments. It systematically organizes three major domains—theoretical framework development, methodological innovations, and practical applications—from current gaps through specific research directions, methodological approaches, to expected outcomes. Particularly, theoretical development in post-pandemic hybrid work models, new measurement methods utilizing digital traces, and practical applications to organizational design and leadership development are positioned as high priorities. This research agenda integrates insights from both corporate virtual teams and MMOGs research, providing research directions for the next decade.

Future technology development should focus on creating platforms that actively support shared leadership behaviors rather than merely providing communication channels. This might include features such as automatic rotation of meeting leadership roles, AI-assisted identification of expertise needs and expert

availability, and collaborative project management systems that distribute leadership responsibilities based on task requirements and individual capabilities.

5. Conclusion

This literature review has demonstrated the remarkable development of shared leadership research from its origins in traditional co-located team research to its current expansion into diverse virtual collaborative environments. The acceleration of this research trajectory since the 2020 pandemic has revealed both theoretical insights and practical applications that far exceed what was previously available in the literature.

The comparative analysis of corporate virtual teams and MMOGs has proven particularly valuable, revealing that these seemingly different contexts share fundamental characteristics while providing unique insights into leadership emergence and effectiveness. Corporate contexts illuminate how shared leadership can be systematically supported through organizational design and technological infrastructure, while gaming environments demonstrate the power of intrinsic motivation and organic emergence in facilitating effective collaborative leadership.

The integration of traditional organizational research with virtual environment studies has revealed significant theoretical and practical opportunities worthy of continued investigation. As organizations increasingly standardize online and hybrid work models as permanent features of operation, understanding shared leadership in these contexts becomes essential for optimizing organizational effectiveness and team performance in the digital age.

This review has several limitations that should be acknowledged. First, the analysis primarily focused on English-language publications, which may have excluded valuable insights from non-English research traditions. Second, the comparative framework concentrated on two specific virtual environments (corporate teams and MMOGs), potentially overlooking other emerging collaborative contexts such as virtual reality platforms or blockchain-based organizations. Third, the current literature provides limited longitudinal data on the long-term effectiveness of shared leadership interventions in virtual settings, highlighting the need for extended follow-up studies to validate the sustained impact of identified practices and theoretical frameworks. Fourth, while this review synthesized literature from multiple disciplines, the relatively limited number of empirical studies specifically examining shared leadership in virtual environments (particularly in gaming contexts) constrains the generalizability of conclusions. Future research would benefit from expanding the evidence base through targeted empirical investigations across diverse virtual collaborative settings.

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Research Note

US-Japan Comparison of Content and Logic for Journalism Fundraising in the Era of AI-Generated Fake News

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Amid AI-generated fake news, journalism as Social Common Capital (SCC) faces declining ad revenue and manipulation. This study qualitatively analyzes fundraising content for journalism by comparing Japan with the United States and other countries. I sampled fifteen organizations (four in Japan, eleven abroad) identified through first-page search results (“ジャーナリズム 寄付” / “journalism donation”) and ChatGPT recommendations. Donation pages were coded for appeal to current events, transparency, value for non-payers (public goods), and emphasis on recurring donations. Inductive codes have also been developed. Outside Japan, dominant logic links pressure on press freedom and shrinking local news with the need for independent journalism and claims that journalism sustains democracy. Across contexts, pages rarely justify why recurring support is essential or address generative-AI misinformation. Japanese pages downplay “independence,” possibly reflecting donor preferences. I discuss the practical implications of media fundraising, chatbots as potential competitors, and directions for future research.

1. Introduction

1.1 Fake News Problem

Although fake news has been observed since antiquity[1], it has become increasingly serious with the advent of generative artificial intelligence (AI). In this study, the term “fake news” includes deepfakes produced by generative AI, dis/misinformation on social media, and conspiracy theories that embed themselves deeply in people’s beliefs[2]. These phenomena are produced and disseminated for economic gain, political advantage, or personal gratification, leading many individuals to hold beliefs that diverge from reality. Claims such as “the Earth is flat (rather than spherical),” “vaccines contain microchips,” or “the planet is not warming” are more sensational than scientifically established information. They are fueled by public anxiety and spread faster than facts. Importantly, such claims are often circulated under the guise of being “scientifically proven.”

The problem of fake news extends beyond media studies into epistemology in philosophy; it is reshaping the fundamental question of how humans can apprehend “reality”[3][4]. No data readily persuade those who hold beliefs grounded in fake news. The concept of conspiracy is effectively unfalsifiable: by asserting that ‘the data have been manipulated by a conspiracy (hence the Earth only appears spherical, etc.)’, any evidence can be dismissed as illegitimate. Today, generative AI makes it extremely easy to fabricate video, images, and datasets that can be presented as “evidence” or “grounds” for a claim. We live in an era in which digital technology makes it remarkably easy to deceive the general public.

1.2 Roles of Journalism and its Funding

Against this backdrop, the role of journalism—politically neutral and tasked with conveying facts to the public—has never become more important. At the same time, numerous cases have been observed in which journalists are targeted at the battlefield. In 2024, at least 124 journalists were killed across 18 countries, the worst figure in just over three decades[5]. Belligerent states clearly recognize that, within the media sphere, the volume of circulation matters far more than whether information is fact-based, and journalists who attempt to deliver facts from the field are treated as obstacles or even enemies of their political objectives. Technologies and organizational apparatuses that systematically generate fake news and related content now function as critical instruments of state power[6]. In an era when vast quantities of outright falsehoods are produced and the information environment is increasingly manipulated by authoritarian regimes and populists, the value of journalism is profound. Concurrently, it is evident that journalism-based media are reaching commercial impasses[7]. As the problems associated with fake news intensify, journalism exhibits positive externalities that justify the support of news organizations through government grants and donations.

1.3 The Aim of This Study

Accordingly, this study considers how to secure funding when journalism is conceived as a shared public good. Specifically, through concrete cases, I analyze the underlying rationales that persuade donors to sustain donation-based revenue for media organizations in the United States and Japan. In doing so, I aim to derive implications for fundraising to support journalism and contribute to the theoretical understanding of donation appeals by news organizations. If we hope that donation-based journalism strengthens as a remedy for fake news problems, its fundamental logic for fundraising messages should be systematically considered and flawlessly constructed in the first place.

2. Literature Review

2.1 Journalistic News Media and Donations

Journalism is now called upon to counter fake news and related phenomena and to report people’s lived realities. However, the media’s business environment in the era of generative AI is severe. Advertising revenues for legacy outlets, such as newspapers, had already declined with the rise of Internet media. Compounding this trend, trust in the media fell in the wake of COVID-19[8]. More recently, search engines have begun displaying summaries generated

by generative AI in result pages, and journalism that migrated online to survive now faces a precipitous drop in traffic, which is the lifeline of advertising revenue. If, going forward, everyday information acquisition shifts from search interfaces to AI agents, preserving the independence of journalism while relying exclusively on advertising[7] becomes practically impossible.

Another revenue option to sustain media is subscription income; however, even in the United States, it appears to have plateaued[9], making revenue diversification a necessary path. Public funding and compensation negotiated with major platform companies has emerged as a pragmatic solution for income diversification beyond advertising and subscriptions. Another promising option for smaller outlets is to operate as a non-profit medium, supplementing advertising and subscriptions with grants and donations. In Japan, although still limited in number, some nonprofit media have begun to solicit donations[10].

However, donations and grants are not a panacea. In some instances, philanthropic funding has been implicated as a source of fake news and related phenomena concerning climate change[11]. Some companies and foundations support nonprofit think tanks or research institutions with intentions to produce "evidence" to deny climate change. Thus, donations can be used to propagate fake news and safeguard journalism.

2.2 News Media as Social Common Capital and its Funding

In theoretical terms, news exhibits the properties of a public good, and the stock that generates public goods is referred to as Social Common Capital (SCC)[12]. This notion is similar to that of the Common Pool Resource (CPR) or Commons by Ostrom[13]; however, SCC can be a macro-scale concept compared with CPR as a community-scale concept. SCC is sometimes owned by private companies, such as power infrastructure and electric companies. News organizations are simultaneously corporate entities and instances of SCC. The normative justification for supporting them through grants and donations rests on internalizing the positive externalities produced by the public goods that SCCs create. Accordingly, a key task in donation appeals to journalism is to communicate the positive societal impact grounded in the concepts of SCC, public goods, and positive externalities to prospective donors. In other words, appeals must articulate not only the value to paying users who purchase information, but also the value created for non-payers.

SCC can be supported through tax revenues; however, because journalistic news media must hold the power to account, relying exclusively on taxes is not appropriate. As mentioned above, dependence on large donations and grants from foundations or corporations heightens the risk that coverage will be distorted by organizations' political and economic interests[11]. Against this backdrop, revenue sources expected to sustain news media that support journalism include individual donations and the use of crowdfunding (CF) to solicit them[14].

CF typically involves small average contributions per pledge on the order of $5–$20 and operates through a comparatively transparent mechanism[15]. While implementing CF imposes substantial burdens on organizations that operate media, including journalists[16], CF that recruits recurring donors rather than one-off gifts is particularly effective for organizations that tackle long-term social challenges[17]. For news organizations, CF aimed at cultivating recurring donors closely resembles campaigns aimed at increasing subscription readership. If organizations that support journalism can expand their base of recurring donors, this is likely to have a positive effect on journalism's sustainability.

2.3 Content for Journalism Fundraising

Prior research has identified journalism quality and support for journalism as motivations for subscribing to news[18]. Conversely, there are reports that while surveillance motivation does not lead to willingness to pay (WTP) for news, entertainment and personal importance are positively associated with WTP[19]. In the media business, WTP is strongly associated with trust in the media[8], and trust is affected by how the use of AI in news creation and dissemination processes is disclosed[20].

Investigative reporting is often cited as a core value of journalism[21], so its content may be effective for fundraising. However, in contexts where articles produced by traditional media are publicly accused of being fake, the importance of maintaining transparency on the part of media organizations is heightened[22]. Transparency also matters for donation appeal in general. In the context of disaster relief fundraising, activity reports that enhance the transparency of crowdfunding projects have been shown to increase donation amounts[23]. Thus, securing transparency is likely to be a critical element in fundraising content.

As for the content of proposals used to promote news subscriptions, three types are identified: informational proposition, social proposition, and normative proposition[24]. They correspond, respectively, to the value of information, the value of connection with others, and the value of changing society[24]. Normative appeal is considered effective as a subscription pitch, and it is reported to be effective in conveying that the subscription model is being implemented because of the decisive financial crisis in the news industry[25]. In donation-based one-off CF campaigns, the appeal of urgent needs is a key element[17]. When soliciting support for recurring-support CF or subscription with normative proposition, it is necessary to answer the question "Why now?" In other words, as a content element, effectively communicating contemporaneous needs, such as the financial crisis in the news industry, is crucial.

2.4 How Donors Find the Content for Journalism Fundraising

How then do prospective donors encounter content that supports journalism? In one pathway, readers browse news articles and are guided to a subscription pitch page. This route is akin to encountering a paywall, where readers decide whether to pay for the information they want. In an environment rich in freely available information, few people pay to cross the paywall[9]. In Japan, donation-based media remains limited, and donors to journalism are said to be few[10]. Therefore, it is not realistic to assume that ordinary readers browse articles and make a donation to the media.

Accordingly, tThis study considers the behavior of individual prospective donors who are proactively motivated to donate to journalism. Although such prospective donors are very few, their strategic priority for donation-based media must be high. Prospective donors may search for donation recipients using search engines. Alternatively, anticipating social changes, we should assume that they will use generative AI such as ChatGPT as an assistant and ask for appropriate donation destinations[26][27] in the near future.

2.5 Research Question and Hypothesis

Based on the above literature, the research question of the present study is: What kinds of content and persuasive logic do news organizations and journalism-support entities actually use when soliciting donations or subscription readers via the Internet? What motivates supporters to contribute? The hypothesis is that the media prefers recurring donations or subscriptions to sustain journalism, and three content factors, namely transparency, current events, and positive externality, are included in the logic for journalism fundraising.

3. Research Methods and Data

3.1 Research Method

Within marketing and public relations (PR) research, qualitative inquiry has long occupied an important position[28], enabling scholars to grasp how communicators attempt to construct social reality. This study analyzes journalism-based news media in Japan and the United States as donation-seeking actors to elucidate the logic by which they solicit contributions. Specifically, this study analyzed (1) how journalistic value, namely the normative proposition[24], is deployed within fundraising content, (2) how the news industry's financial crisis is invoked[25], and (3) how transparency is enhanced[22]. Given these aims, qualitative methods to deeply investigate top organizations are considered more appropriate than quantitative approaches to check numerous organizations that might have ineffective fundraising content. This is because this study aims to understand the real fundraising content and effective logic that proactive donors read when they search for journalism organizations.

3.2 Research Design and Data Collection

This study examined the content that individuals interested in donating to support journalism would likely encounter in each organization. The author searched for journalism organizations to give and accessed websites appearing on the first page of results in Google's search engine, collected the recipient organizations' pages, and conducted a qualitative content analysis. A comparative analysis of the donation appeals shown on the first page of the search results was performed. As a reference, this study also examined which recipient organizations would be recommended when generative AI was provided with a prompt indicating the intention to donate to journalism.

The searches and generative-AI prompting were carried out on August 23–24, 2025. To avoid recommendations based on prior browsing history, the searches were executed in a logged-out state using Google in the private mode. For Japanese websites the keyword「ジャーナリズム 寄付」was used. For English-language websites (e.g., in the United States), the keyword "Journalism donation" was used.

Regarding the use of generative AI, ChatGPT4o's temporary chat feature was employed to eliminate the influence of past conversation history, using the prompt:「ジャーナリズムへの寄付を考えています。寄付先に相応しい日本の団体を3つ推薦してください」. For English-language organizations, the prompt: "I am considering making a donation to journalism. Please recommend three appropriate organizations in the United States to which I can donate" was used.

3.3 Journalism Organization Sample

In the Google search conducted in Japanese, the following organizations were identified: J-Forum[29], Medical Journalists Association of Japan (MEJA)[30], Citizen Fund for Journalism Support[31], and The Tokyo Investigative Newsroom Tansa[32]. An additional journalism-related donation destination appeared on the search results page; however, its website did not support https and could not be accessed by the browser. In ChatGPT, Tansa, J-Forum, and the Citizen Fund for Journalism Support were recommended, yielding a total of four organizations for investigation.

In the English-language Google search, the following organizations were identified: Society of Professional Journalists[33], The Wire India[34], Committee to Protect Journalists[35], American Journalism Project[36], International Consortium of Investigative Journalists (ICIJ)[37], National Public Radio (NPR)[38], The Guardian[39], Asian American Journalists Association (AAJA)[40], European Journalism Centre (EJC)[41]. In ChatGPT, the American Journalism Project[36], Report for America (RFA)[42], and Freedom of the Press Foundation (FPF)[43] were recommended, resulting in a total of 11 organizations for investigation.

As noted above, this study sampled the donation-appeal pages of four organizations in Japan and 11 organizations in the United States and other English-speaking contexts. Content from the fifteen organizations was imported into MAXQDA Analytics Pro (24.10.0). Based on the hypothesis, three codes were prepared: appeals to timeliness/current affairs, ensuring transparency, and value for nonpayers (positive externality). The author also coded whether recurring donations were solicited more strongly than other forms of giving (e.g., setting them as the default option). In addition to these four top-down (deductive) codes, bottom-up (inductive) coding was conducted while observing the data.

Furthermore, as patterns might differ between 1) organizations that conduct reporting and 2) those that support such activities, the author categorized organizations into these two types.

4. Results

First, for the 15 organizations examined, the author compiled an overview together with the top-down coding results (Table 1). Five organizations, two in the United States, one in the United Kingdom, one in India, and one in Japan, directly conduct reporting. The remaining ten organizations support journalists and news outlets. All five reporting organizations emphasized recurring donations (Table 1), which was consistent with the hypothesis. The U.S. and U.K. outlets[37][38][39] solicit recurring donations using content on their transparency.

4.1 Recurring Donations and Transparency

Content designed to enhance transparency varied considerably across organizations. For example, the ICIJ's donation page includes the COO's headshot and message as well as an e-mail link, clarifying who will put the donation to use[37]. On the NPR's donation page, donors can choose to give either to a Local Station—that is, a specific station within the NPR network—or to the NPR itself[38]. The Guardian displays the current number of recurring donors, the target number in a bar chart, and the deadline for achieving that target[39]. Japan's Tansa features

content elements similar to those of the Guardian and U.S. outlets, including a comparable bar chart[32].

Likewise, among organizations that support outlets or journalists, transparency has been pursued in various ways. At the EJC and AAJA, direct support to initiatives is possible[40][41], thereby clarifying the use of funds for donors. With respect to conflicts of interest, only MEJA publicly disclosed the status of donations received[30].

4.2 Value for Non-Payers and the Commons

Many organizations explicitly appeal to the idea that news provided by reporting outlets is a public good whose benefits extend beyond those who finance it. ICIJ states to donors its aim of a society without corruption, injustice, and inequality[37]. NPR emphasizes that a trusted public service that is freely available benefits not only the donor but also millions of others[38]. Some pages also cite donors' own words to argue that journalism helps create a better world[37]. Among Japanese organizations, phrases such as "free and fair society"[31] and "quality of reporting"[30] appeared. An explicit claim that journalism is a public good was found in only one Japanese organization[31].

Few organizations have highlighted donor-exclusive benefits such as access to articles unlocked by donating. Of the 15, only The Guardian and Medical Journalists Association of Japan (MEJA) did so[30][39] on their fundraising pages.

4.3 Appeals to Current Events and to Democracy

As appeals to current events, U.S. organizations have highlighted the deterioration of press freedom[33], the threat to democracy posed by the decline of local news[36], and cuts to federal funding for public media[38]. In this context, there are also examples asserting that the work of professional journalists is more necessary than ever[33]. Likewise, the EJC appeals for donations against the backdrop of mounting pressure on journalism[41]. In short, these appeals employ the following logic: (1) mounting pressure on press freedom and a weakening supply of local news, (2) the need to strengthen journalism, and (3) the maintenance of democracy. In Japan, there were instances citing press freedom rankings[31], but none explicitly adopted the logic of safeguarding democracy through journalism. Similarly, Japanese equivalents of terms such as independent and fearless were rarely observed among Japanese organizations; the exception was Tansa, which referenced independence as an investigative reporting organization[32].

4.4 Content Elements Identified through Bottom-Up Coding

Although not included among the initial codes, the analysis surfaced an appeal stating that "journalism depends on your donation" or "we cannot operate without your support." This takes the form of claims, such as relying principally on donations from readers and donors, which is essential for journalism[34], and that the organization's work depends on your donation[33][35][43]. Theoretically, such claims are plausible appeals to prevent free riding on a public good. Outside the United States, such phrasing was either absent or stated more softly—for example, "with your support, we can continue"[29] or "this can be realized"[41].

Some organizations emphasize their many years of activity, which appears to be effective in asserting the trustworthiness of the recipient organization[33][34][40][41].

Bottom-up coding also identified cases reflecting new donation trends, such as accepting donations via the Donor-advised Fund (DAF)[35][36] and cryptocurrency. These acceptance methods can carry the risk of receiving opaque donations. Outside the United States, we found no organizations that mentioned accepting DAF or cryptocurrency donations.

Conversely, there were cases explicitly stating that certain donations or funding would be declined. For instance, Tansa does not accept advertising revenue from governments or corporations and may decline corporate donations to preserve independence[32]. The Wire stated that only Indian citizens could support the organization[34]. The Guardian emphasizes that it has neither a corporate nor a billionaire owner and can therefore state the truth about the climate crisis[39]. The ICIJ also states that 100% of its revenue comes from donors[37].

Finally, in an era rife with criticism of journalistic overreach, some organizations used the phrase ethical journalism[33] or noted compliance with a code of ethics[37]. Conversely, others have cited instances of attacks against journalists to underscore the need for support[35].

4.5 Content Elements That Were Not Addressed

From the content analysis, while it became clear that recurring donations are especially important for reporting organizations, there were almost no instances that directly explained why recurring support is necessary for journalism. Such explanations may, of course, be conveyed outside the donation application page (e.g., in banner ads that funnel users to the donation page). However, if a page that prospective donors will inevitably view asserts that recurring gifts are "the best way to fund our journalism"[39], then providing even a brief rationale would likely strengthen persuasive logic. An exception was Tansa, which stated that recurring donations constitute a stable revenue base that sustains the organization[32].

Second, among the appeals to current events, I found no organizations explicitly addressing societal changes driven by generative AI or the heightened necessity of journalism in the era of fake news and related phenomena. Fake news is closely intertwined with the condition of democracy. In recent years, facts have been losing their status as a shared foundation for agreement among actors with opposing positions[6]. Now that, at least for some political actors, facts have become relative and objects of strategic manipulation, journalism plays a substantial role.

Third, descriptions of journalists' professional expertise were largely absent from the sampled content. In philanthropy, donations oriented toward building a better society over the long term, lay donors find it difficult to assess the quality of a recipient's activities. Therefore, some form of authoritative signaling is likely to be effective[44]. In this regard, highlighting an organization's awards can reasonably appeal to donors. However, in the sample, the phrase award-winning appeared only once[37], and even Tansa, which won multiple prizes, did not foreground its award history. Given that journalism's mission is to question authority, it may be inherently difficult to rely on prestigious awards as credible devices.

5. Discussion

5.1 Core Logic Supporting Donations to Journalism

In our sample, the dominant logic on fundraising pages outside Japan consists of the following linked propositions:

1. We live in a period of mounting pressure on press freedom and a weakened supply of local news (contemporaneous context).
2. Thus, strengthening independent journalism is necessary for society as a whole.
3. Doing so sustains democracy and a fair society (positive externalities; journalism as a public good).
4. Realizing this depends on your donation; funding that could compromise independence is declined.
5. The transparency of fund use and progress toward goals is ensured.

This logic was partially echoed among Japanese organizations and, consistent with prior research, reporting outlets, in particular, appeared to seek a stable operating base by cultivating recurring donors.

At the same time, although all reporting organizations primarily solicited recurring gifts, I found little explicit reasoning as to why such support was needed. Moreover, there have been few references to the era of generative AI, fake news, and related phenomena, or the resulting transformation of the premises of democracy.

Among Japanese organizations, the connection to democracy was not stated. The same held when I asked ChatGPT in Japanese to recommend donation recipients: the responses did not include the term "democracy." When I used an English prompt to have ChatGPT recommend journalism donation recipients, the term Democracy did not appear either, although there was mention that news is necessary for civic engagement.

Our analysis also suggests that Japanese organizations do not necessarily lack key content elements; some features appeared only among Japanese cases. Philanthropic research in Asia notes that donors in the region often prefer recipient organizations aligned with government agendas[45]. In light of such market characteristics, the relatively modest emphasis on independence by Japanese organizations may not be a disadvantage. Indeed, even AAJA, an Asian-American organization in the United States, did not use the term independence[40].

5.2 Potential Competitive Alternatives to Donations to Journalism

For citizens, distinguishing articles and images produced by high-quality journalism from those that are not is difficult. In an era of fake news that fully leverages generative AI, this distinction is becoming exponentially more difficult. The idea has already been proposed that generative-AI-based fact-checking functions[46]. It is conceivable that, instead of subscribing to or donating to particular outlets, people will come to entrust (and pay for) their own fact-checking to AI-based personal assistants. As a sign of this, young people already consume news via social media[47]. Even articles produced by established news organizations are likely to be subject to scrutiny by readers' generative-AI assistants. In response, newsrooms are likely to deploy generative AI extensively before publication. Therefore, research is needed on the use of generative AI for fact-checking and on news organizations' own use of generative AI. News outlets and journalist support organizations should remain vigilant regarding these potential threats.

Policy makers responsible for social infrastructure will inevitably need to assess whether grants to individual news organizations or grants to develop trustworthy personal assistants are more effective in guaranteeing the public's right to know and consider whether to cultivate one or both as SCC. Future work must also examine which business models personal-assistant providers adopt and how these models affect the quality of fact-checking.

5.3 Limitations of This Study

This study is limited in that it analyzes only a very small subset of top organizations' fundraising communications. Organizations that appear at the top of the search results are not necessarily the best choices for donations. Additionally, only the donation application pages within the online donation process were analyzed. Although our page selection targeted scenarios that new donors give via the Internet, organizations may use richer content and more refined, or even different, persuasive logics when addressing existing donors. A more comprehensive analysis of organizations' communication strategies could yield more substantive data, which remains a task for future research.

Moreover, because I did not sample donation recipients personalized to individuals, people who actually intend to donate to journalism may be shown recipients that differ from our sample; this constitutes another limitation. While, in this study, there was no major discrepancy between recipients shown on the first page of search results and those recommended by generative AI, if Search Engine Optimization is supplanted by optimization for generative AI[48], it may become necessary to analyze not donation-page content but rather the explanations that generative AI produces—tailored to each user's interests.

6. Conclusion

Amid the growing importance of journalism as an SCC in the era of fake news and related phenomena, media outlets have suffered declining advertising revenues and face severe financial constraints. Donations, therefore, constitute an important revenue stream. This study analyzed the logic employed in donation appeals for journalism. In conclusion, while I identified stylized logic (as presented in the Discussion), I found little explicit reasoning—both among Japanese outlets and those in the U.S. and elsewhere—either justifying recurring donations or grounded in digital technologies such as generative AI. These gaps suggest areas where scientific research on fundraising and digital technologies (including generative AI) can meaningfully contribute to journalism.

Looking ahead, as the importance of fact-checking increases, generative AI may perform this role as a personal assistant. How journalism can continue to safeguard the foundations of a healthy society while navigating the technological transformation represented by generative AI remains a critical challenge.

Table 1: Sample organizations and the top-down coding results

Organization name	Headquarters	Directly conduct reporting	Prioritize recurring gifts	Transparency	Current events	Positive externality
Society of Professional Journalists	USA		○		○	○
The Wire India	India	○	○			
Committee to Protect Journalists	USA					
American Journalism Project	USA				○	○
International Consortium of Investigative Journalists	USA	○	○	○		○
National Public Radio (NPR)	USA	○	○	○	○	○
The Guardian	UK	○	○	○		
Asian American Journalists Association	USA			○	○	
European Journalism Centre	Netherlands			○	○	○
Report for America (RFA)	USA					○
Freedom of the Press Foundation (FPF)	USA		○			
J-Forum	Japan		○		○	
Medical Journalists Association of Japan (MEJA)	Japan		○	○		○
Citizen Fund for Journalism Support	Japan				○	○
The Tokyo Investigative Newsroom Tansa	Japan	○	○	○		

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Research Report

Rapid Fabrication Process of Digital Dentures in Disaster Situations and a Feasibility Study on Production Time

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This study evaluated the feasibility of rapid digital denture fabrication under disaster-simulated conditions using an intraoral scanner and 3D printer, involving three healthy adult males with single posterior tooth loss scanned with TRIOS 5 in a simulated evacuation shelter where denture design by a technician required 9–14 minutes and intraoral scanning 9–13 minutes, followed by 15 minutes for 3D printing, 32 minutes for washing and polymerization, and 46 minutes for polishing, adjustment, and fitting, with the entire workflow from entry of the first participant to delivery of the final denture completed in 3 hours and 41 minutes, thereby demonstrating that on-site digital dentures can be provided within a few hours, a dramatic reduction compared with conventional 1–2 month fabrication, and suggesting that mobile dental units equipped with scanning and printing technology (medical MaaS) could offer a practical solution for rapid oral rehabilitation in disaster response and remote healthcare settings.

1. Introduction

In disaster situations, it has been reported that a certain proportion of elderly people lose their dentures or fail to bring them during evacuation. For example, following the Great East Japan Earthquake, approximately one-fifth of denture wearers either lost their dentures or did not carry them during evacuation[1]. The absence of dentures is a serious problem, as it directly leads to impaired masticatory function, malnutrition, aspiration pneumonia, and reduced quality of life (QOL). In recent years, advances in digital denture fabrication using intraoral scanners and 3D printers have made immediate denture production feasible[2]. With internet connectivity, scan data obtained in evacuation shelters can be transmitted to remote dental laboratories for design and fabrication, while 3D printing of the denture can be performed on-site[2]. This has the potential to revolutionize the provision of dentures in disaster scenarios[3]. Furthermore, the use of mobile dental units equipped with scanners and 3D printers (so-called medical MaaS) enables direct provision of denture fabrication and delivery at disaster sites and in medically underserved areas. This approach not only contributes to disaster response but may also improve access to routine dental care.

2. Objective

The purpose of this study was to measure the actual fabrication time of digital dentures using intraoral scanners and 3D printers under conditions simulating a disaster, and to establish a rapid and practical workflow for denture provision.

3. Methods

Three healthy adult males (aged 50, 51, and 51 years) participated in the study. Their missing teeth were as follows: mandibular right first molar, mandibular left second premolar, and mandibular right first molar. The experiment was conducted in a Japanese-style room with simple mats and pillows, simulating an evacuation shelter environment. An intraoral scanner (TRIOS 5, 3Shape) connected to a laptop PC was used. Each participant underwent scanning sequentially, and the required time was recorded. The scan data were sent to a dental laboratory, where a dental technician performed digital denture design. The final design data were transferred to a 3D printer installed at the shelter, and the entire workflow—printing, washing, polymerization, polishing, adjustment, and fitting—was documented.

4. Results

The scanning times for each participant were as follows: Participant 1: 13 min 29 sec (from room entry to scan completion; 3 min 40 sec from entry to scan start) Participant 2: 10 min 34 sec (1 min 26 sec) Participant 3: 9 min 40 sec (2 min 22 sec) The times required for denture design at the dental laboratory were: Participant 1: 14 min 10 sec Participant 2: 12 min 32 sec Participant 3: 8 min 57 sec Following nesting, 3D printing required 15 min 14 sec, washing and polymerization required 32 min 23 sec, and polishing, adjustment, and fitting required 45 min 40 sec. Overall, the total time from the first participant's room entry to the final denture fitting for the third participant was 3 hours 41 min 36 sec.

5. Discussion

This study demonstrated that a single-tooth denture can be fabricated and delivered within approximately 3 hours 40 minutes under disaster-simulated conditions. Compared with the conventional denture fabrication process, which often requires 1–2 months, this workflow achieved significant time reduction and may contribute to rapid restoration of oral function in disaster settings[4]. Of the total fabrication time, dental procedures (scanning, fitting, and adjustment) required about 20 minutes, while denture design by the dental technician required approximately 10 minutes. The majority of time was consumed by 3D printing and polymerization.

Therefore, during these waiting periods, dental professionals could attend to other evacuees, conduct examinations, or provide oral care, highlighting the high practicality of this workflow in disaster situations. The use of mobile dental units equipped with scanners and 3D printers enables immediate on-site denture provision at evacuation shelters or temporary housing. This has the potential to fundamentally transform dental care delivery in disaster-stricken or resource-limited areas and represents a practical application of medical MaaS. Nevertheless, while 3D-printed dentures offer reduced polymerization shrinkage and superior fit, the study also revealed the necessity of fine adjustments[5]. Careful design of undercuts and the presence of skilled dental technicians capable of making chairside adjustments are crucial. This study examined relatively simple single-tooth cases. Future research should expand to multiple-tooth loss and edentulous cases[2]. In disaster situations where postal infrastructure is available, the fabrication of high-precision milled dentures at dental laboratories, followed by delivery to the site, also warrants consideration[5].

6. Conclusion

This study confirmed that digital dentures fabricated with intraoral scanners and 3D printers can be completed within approximately 3 hours 40 minutes under disaster conditions. Compared with conventional denture production timelines, this represents a major reduction in time, offering an effective means to mitigate health risks associated with denture loss during disasters. Moreover, mobile dental units equipped with scanners and 3D printers allow for immediate on-site response, expanding the possibilities of medical MaaS in disaster care, home care, and underserved regions. Future challenges include validating the workflow for edentulous and multi-tooth loss cases, evaluating long-term durability and comfort of the dentures, and establishing standardized protocols for integration of mobile dental units into disaster medical systems. In parallel, strengthening digital technology training for dental professionals will be essential. The integration of mobile dentistry and digital denture technology holds the potential to reshape not only disaster response but also everyday dental practice.

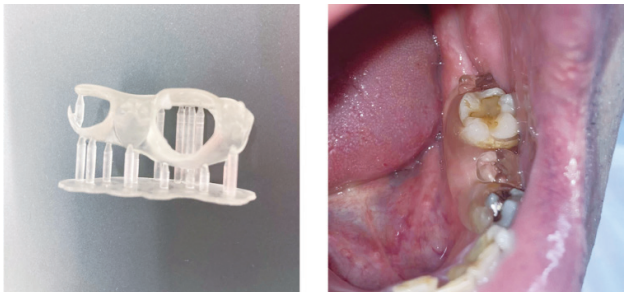

Figure 1: Fabricated digital denture and intraoral view at delivery

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