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Remodeling the *Leiqin* Leg Rest with Additive Manufacturing: Enhancing Performers' Learning Interest

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Abstract

This study employed a combination of experimental methods and semi-structured interviews to explore the application of additive manufacturing in remodeling the *leiqin* leg rest and to evaluate its impact on performers' learning interests. During the remodeling process, the leg rest was optimized with a dual-layer, rotatable structure and an arched texture at the base, which conforms to the natural curvature of the leg, enhancing friction and fit. These design improvements significantly increased comfort, stability, and personalized adaptability. Additionally, the enhanced stability contributed to improved sound quality. The improved playing experience further stimulated musicians' learning motivation. This study not only provides practical insights for personalized instrument design but also offers new perspectives for future research in musical instrument manufacturing and music education.

Keywords: Additive Manufacturing, *Leiqin* Leg Rest, Performance Experience, Learning Interests, Positivity

Introdution

In the modernization and remodeling of traditional musical instruments, the ability to integrate classical design principles with emerging technologies has consistently been a central research focus. Additive manufacturing (AM), commonly known as 3D printing, constructs objects layer by layer, enabling the creation of complex geometries that are challenging to achieve through conventional design and manufacturing methods. This technology offers significant advantages, including high design flexibility, personalized customization, lightweight structures, and material optimization (Liang-Yu et al., 2024). In recent years, AM has been widely applied in fields such as medical rehabilitation devices, sports equipment, and musical instrument manufacturing (Odera & Idumah, 2023). This technological advancement not only provides innovative solutions to the ergonomic challenges long faced by musicians but also offers renewed hope to learners who have discontinued their musical education due to comfort-related issues (León & Galindo, 2022).

The *leiqin* is the youngest member of the Chinese *huqin* family, having been created only a century ago. This instrument was developed in the late 1920s by Wang Dianyu, a renowned traditional instrumentalist from Shandong Province, China, and has since held an important place in Chinese folk music due to its distinctive timbre and expressive capabilities (Song, 1984). However, within the modern music education system, the popularity of the *leiqin* remains relatively low compared to other traditional instruments, particularly among younger generations (Fu, 2017).

One of the factors contributing to this phenomenon is the design of the *leiqin*'s leg rest. As a crucial accessory that supports the instrument during performance, the current leg rest is made of solid wood, shaped as a square block, and features a uniformly smooth, flat bottom. This design reduces the friction between the instrument and the player's leg, which may lead to slipping, especially for beginners who lack precise control over their playing pressure, potentially resulting in performance accidents (Jia, 2015). Furthermore, the flat design of the leg rest can cause discomfort for musicians during prolonged practice sessions, negatively affecting their overall playing experience (Yang, 2019). These design limitations not only hinder the learning interests of performers but also impact the overall playing performance. Julia (2019) noted that reasonable structural modifications to traditional musical instruments can enhance performance, reduce learning difficulty, and further stimulate learners' motivation. Therefore, optimizing the ergonomic properties of the *leiqin* leg rest to improve the playing experience and exploring innovative design solutions has become a pressing necessity.

The introduction of AM offers new possibilities for addressing the aforementioned issues. Research indicates that integrating AM into instrument manufacturing not only simplifies production processes but also expands the potential for design innovation, resulting in instruments that are both functionally superior and aesthetically unique. For example, Marano (2019) utilized AM to create an ergonomically designed electric guitar, while Barinque (2022) developed a lightweight and cost-effective violin chin rest using this technology. Barinque also highlighted that AM enables the creation of complex shapes and unique functionalities that traditional manufacturing techniques cannot easily achieve, thereby significantly enhancing player comfort and the overall learning experience (Grabowy & Niedbala, 2024).

Based on the above background, this study aims to explore the feasibility of remodeling the *leiqin* leg rest using AM to enhance its ergonomic properties. Through semi-structured interviews, the study evaluated *leiqin* performers' experiences with the remodeled leg rest in terms of comfort and stability. This research not only contributes to improving the playing experience of learners but also enhances the acceptance and interests of younger generations in *leiqin*, thereby promoting its integration and development within modern music education systems.

Method

1) Research Requirements

This study is involved four stages: (1) Finding the defects and designing the leg rest. (2) Design the plan of remodeling leg rest. (3) Manufacture the improved leg rest. (4) Acoustic test of the remodeled leg rest.

To ensure data accuracy, this study invited 10 *leiqin* performers to participate in a comfort and stability test after each leg rest remodel and evaluate their experience. Each interview lasted approximately 30 minutes. The feedback collected through semi-structured interviews provided additional support for the interpretation of the research findings, thereby enhancing the study's validity and reliability. The information of the ten performers is shown in Table 1.

Table 1
The Information of the Ten Performers

Performers	On *leiqin*'s maturity
P1	*Leiqin reformer and performer*
P2	National non-genetic inheritor of **leiqin**
P3	Provincial non-genetic inheritor of **leiqin**
P4	*Leiqin performer and professor*
P5	City-level non-genetic inheritor of **leiqin**
P6	*Leiqin performer*
P7	*Leiqin performer and professor*
P8	Student of *leiqin*
P9	Student of *leiqin*
P10	Performer of *leiqin*

In leg rest design, process management, and design engineering, the Theory of Inventive Problem Solving (TIPS) is widely applied (Indrawati & Shabrina, 2023). TIPS integrates a structured and systematic approach to problem-solving with analytical and forecasting techniques to address design challenges (Altshuller, 1996). In this study, the contradiction matrix incorporates factors such as object-generated harmful effects, duration of action, weight distribution, shape, and the stability of the object's composition. To resolve these contradictions, the TIPS matrix suggests several inventive principles, including local quality enhancement, dynamic adaptability, substitution of mechanical systems, transformation of material properties, and the use of composite materials. The conflict resolution process is illustrated in Figure 1.

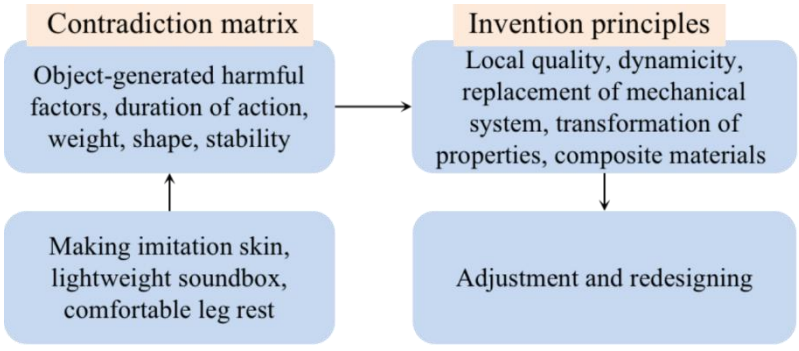

Figure 1. TIPS methodology for the *leiqin* leg rest

To achieve the ergonomic *leiqin* leg rest remodel, it is crucial to identify the parameters and factors that influence the design. These factors include the intensity of playing, the player's posture, and the placement of the leg rest during playing. All of these aspects must

be taken into consideration to meet the musical requirements and ensure personal comfort. This study draws upon the insights of Richard Ward, "How to choose the right chinrest for violin/viola", to inform the development of a more ergonomically sound *leiqin* leg rest.

Design of Remodeling Leg Rest

The remodeling of the *leiqin* leg rest was developed and executed by Qingze Design Studio in Jinan, Shandong Province, China. Taking into account the varying heights and sizes of players, the bottom curvature of the leg rest was specifically designed to ensure ergonomic suitability for the majority of individuals. In this study, researchers employed a handheld three-dimensional laser scanner (Leader 3D T22) to scan the legs of the players and collect initial data on their leg dimensions. To maintain consistency and clarity, only the measurements of the players' left legs were taken, as this side is typically the most dominant and commonly used, as illustrated in Figure 2.

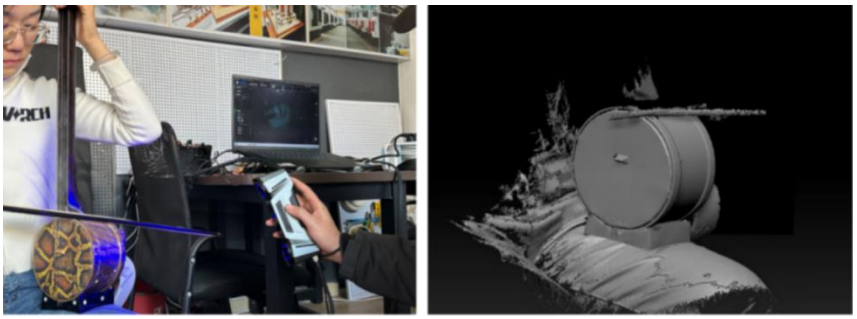

Figure 2. 3D Processes Involved in the Leg Scanning

Following the leg rest scanning, the 3D model was generated using Rhino 7.3, a computer-aided design software developed by Rhinoceros International Co., Ltd. (USA), and subsequently exported in STL format. The model was then processed using Magics 26.1, a 3D printing preparation software developed by Materialise (Belgium), to optimize its structure for fabrication. Each printing process took a total of 20 hours, after which the prototype was tested and refined to achieve the final product.

Result

Finished Remodeling Leg Rest

The material used for remodeling the leg rest is a photosensitive resin, composed mainly of polymer monomers and prepolymers, along with a light initiator like ultraviolet light or photosensitizer. This material has become increasingly popular and well-regarded in the expanding field of 3D printing due to its exceptional properties. The final design of this study includes a double-layer rotatable leg rest for the *leiqin*. The upper layer features a curved top that seamlessly connects with the soundbox, ensuring its secure placement. It has a smooth and flat bottom with a screw hole. The top of the lower layer is also smooth and flat, connected to the upper layer with screws. The bottom of the lower layer is curved to better fit the performer's leg curve, with a non-slip texture for increased contact area. The upper and lower layers are connected by screws, with a raised ring structure in the middle for positioning assistance. This double-layer design improves the stability of the *leiqin* and facilitates easier angle adjustments during play, as shown in Figure 3.

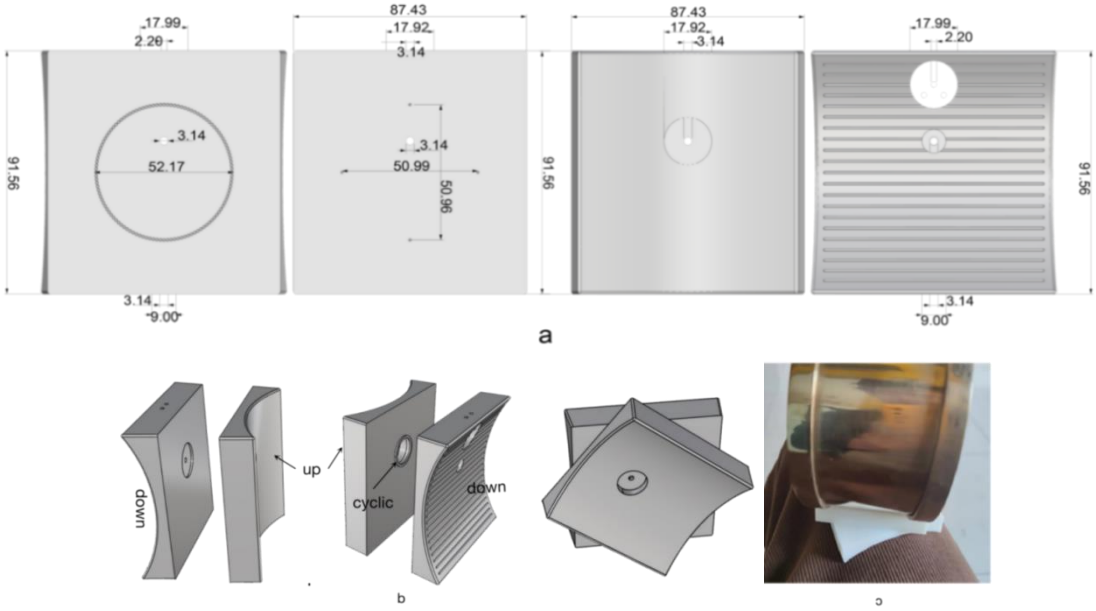

Figure 3. Process of remodeling the leg rest
(a. Remodeling the plane dimensions of the leg rest; b. 3D display of remodeled leg rest; c. Final presentation of the remodeled leg rest)

Interview Analysis of Remodeled Leg Rest

The remodeled leg rest manufactured using AM overcomes the disadvantages of a smooth and flat bottom while also allowing for rotational adjustment to accommodate different performers. Based on the analysis of interview data, four concepts were identified: (1) User Experience, (2) Learning Interest, (3) Sound Quality, and (4) Recommendation. Table 2 presents the consensus of the 10 interview participants, "1" represents the performer's perspective.

Table 2
Opinions on Remodeling the Leg Rest

Concepts	**Codes**	**Statements**	**Performances**									
			P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
User Experience	comfortability	This leg rest conforms better to the ergonomic shape, distributing pressure during performance.	1			1	1		1	1		1
		When playing now, I can hardly feel any pressure from the leg rest on my thighs.	1		1			1				
		The design of the leg rest makes me feel less fatigued.		1	1	1			1			1
		The material of the new leg rest prevents my legs from feeling sore during long practice sessions.	1					1		1	1	
	peisonalizatio n	While playing, I can feel the leg rest as part of my body, making the performance more natural.		1	1		1		1		1	
		Now, I can adjust the angle of the leg rest to accommodat e different sitting postures.	1			1				1		

		This shape fits my leg type better.			1				1			1	1
	stability	Even when playing fast, the leg rest remains stable.	1		1	1	1		1				1
		The anti-slip design at the bottom of the new leg rest makes it much more stable, so I no longer need to make additional posture adjustments.			1				1			1	
Learning Interest	practicing	The new leg rest has reduced the instances where I had to interrupt my practice due to physical discomfort.			1		1						1
	concentration	I can focus on practicing for longer periods, now.	1		1				1				1
	study	The stability of the remodeling leg rest gives me more confidence in my playing, making me more willing to learn the leiqin.	1		1		1			1	1	1	
		The new leg rest is more suitable, making playing more relaxed, and I			1				1			1	

		am more willing to invest time in practicing.										
Sound Quality	timbre	After the stability of the leg rest was enhanced, the tonal continuity became stronger, and the expressiveness improved.	1			1				1		
		After using the new leg rest, I found that the tonal sustain was better.	1			1	1		1		1	1
	sound	Although the material changed, the tone itself did not change.		1	1			1				1
Recommendation	beauty	I hope to add some patterns to the appearance to enhance aesthetics.	1		1	1			1		1	
	thickness	I am relatively short, so I hope the height can be further optimized.	1				1					1

In the interviews, it was generally believed that, compared to the traditional design, the remodeled leg rest provided greater comfort during long playing sessions. The curved bottom design offered better stability than the thinner leg rests. Although the material was changed, the sound quality remained stable and even improved. The rotatable leg rest allowed for more flexibility in handling playing postures. By enhancing the stability and comfort of the leg rest, more performers showed an increased interest in learning.

Of course, some performers mentioned that while the dual-layer design has ergonomic advantages, the added thickness affects their accustomed hand positioning. They suggested reducing the thickness while maintaining the current design. Additionally, some performers expressed a desire for more color options on the leg rest to enhance its aesthetic appeal.

Based on these findings, the structural model developed in this study is shown in Figure 4.

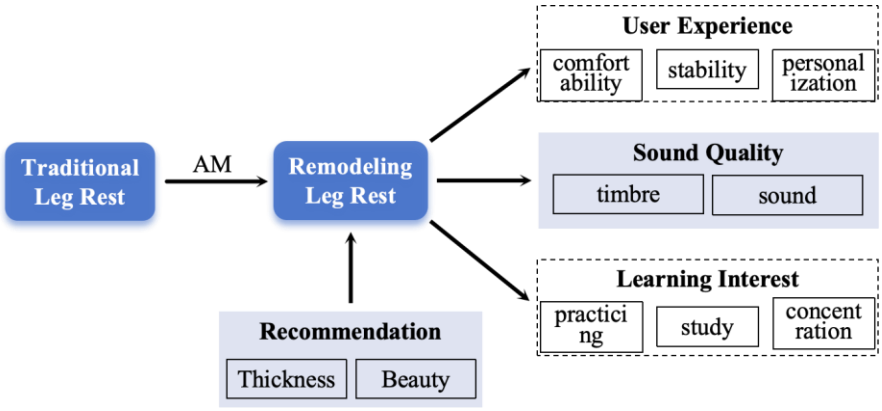

Figure 4 .Structural model of this study

Discussion

This study explores the impact of redesigning the *leiqin* leg rest using AM on performers' learning interests and playing experience. The results indicate that the remodeled leg rest significantly outperforms the traditional design in terms of comfort and stability, while also improving sound quality to some extent. Consequently, it effectively enhances players' learning interests and practice motivation.

Advantage of AM

AM, by stacking materials layer by layer, enables the creation of complex geometric shapes while offering a high degree of design freedom and material-saving advantages (Liang-Yu et al., 2024). In this study, 3D printing technology was successfully applied to remodel the *leiqin* leg rest, fully demonstrating its potential in geometric design and personalized manufacturing. Compared to traditional manufacturing methods, AM allows for the rapid generation of highly adaptable leg rest designs based on the player's body characteristics and playing habits. This effectively addresses the issues of lack of customization, low comfort, and poor stability in traditional leg rests, further validating the application value of AM in musical instrument manufacturing (Domingos Dias et al., 2024).

Enhancement of User Experience

Interview analysis revealed significant improvements in user experience with the remodeled leg rest. First, the use of AM allows for personalized customization based on the anatomical characteristics of the performer's leg, ensuring a high degree of fit between the leg rest and the leg. This helps distribute the overall pressure of the *leiqin*, thereby reducing discomfort. Second, the addition of anti-slip textures and a dual-layer rotating design further enhances the instrument's stability during performance, minimizing performance accidents caused by slipping or rapid bowing. This result aligns with the successful applications of AM in the medical field, such as 3D-printed prosthetics and orthotic devices (Kumar et al., 2025), further demonstrating its potential in improving user experience.

Improvement in Sound Quality

The study found that the remodeled leg rest not only enhanced playing comfort and stability but also had a positive impact on the sound quality of the *leiqin*. The improved stability reduced unnecessary vibration interference, resulting in a purer, more coherent tone with

enhanced expressiveness. This finding aligns with perspectives in organology research (Brezas et al., 2024), which suggest that optimizing the structure of a musical instrument can improve its acoustic performance and enhance overall playing quality.

Improvement in Learning Interest

The combined enhancement of comfort, stability, and sound quality directly boosted performers' confidence and sense of control over the instrument. Participants generally reported that the remodeled leg rest made them more willing to invest time in practice and reduced interruptions caused by physical discomfort. Additionally, the rotatable leg rest accommodated players with different postures, further increasing their interests in learning. This aligns with previous studies on the impact of technological optimization on learning efficiency (David & Weinstein, 2024). Such a positive experience helps cultivate and sustain interests in learning the *leiqin*, effectively promoting its integration into modern music education systems.

Conclusion

This study systematically explored the application of AM in remodeling the *leiqin* leg rest, evaluating its performance in terms of comfort, stability, and personalized adaptation, as well as its impact onperformers' learning interests. The findings indicate that 3D printing technology is highly suitable for reshaping the *leiqin* leg rest, achieving significant improvements in comfort, stability, and adaptability. These enhancements effectively increased players' learning motivation and practice engagement, providing new design insights for *leiqin* leg rests while also serving as a valuable reference for the modernization of traditional musical instruments. The introduction of AM allows instrument manufacturing to better meet users' personalized needs, thereby significantly enhancing the playing experience and learning interest.

Filling Gaps in Existing Literature

This research addresses several key gaps in the existing literature related to traditional musical instrument design, AM applications, and music education. First, while previous studies have examined the historical evolution, playing techniques, and acoustic properties of traditional Chinese instruments (Jia, 2015; Fu, 2017), few have systematically investigated ergonomic issues associated with instrument accessories. The design of the leiqin leg rest has long been overlooked, despite its critical role in performance stability and user comfort. This study fills this gap by introducing a new approach to optimizing the leg rest, demonstrating that structural remodeling can significantly enhance both player experience and playing stability.

Second, research on AM in musical instrument design has predominantly focused on Western instruments, such as electric guitars (Marano, 2019) and violin chin rests (Barinque, 2022). However, its application in traditional Chinese instruments remodeling largely unexplored. This study extends the scope of AM research by demonstrating its effectiveness in improving the functionality of a traditional Chinese instrument. By employing AM to create an ergonomically optimized leg rest, this study expands the potential for digital manufacturing in traditional instrument craftsmanship.

Third, although existing studies on music education and learning motivation emphasize psychological and pedagogical factors (Oliveira et al., 2021; Sun, 2024), they often overlook the influence of instrument design on engagement. This study provides empirical evidence that improving an instrument's comfort and stability through AM directly enhances performers' willingness to practice and sustain learning interest. The findings suggest that ergonomically optimized instrument components can contribute to long-term motivation and reduce learning fatigue, highlighting the critical role of physical design in music education.

Advancing Theoretical Understanding

This research offers several theoretical contributions that advance interdisciplinary understanding across the fields of music education, ergonomics, and AM applications. First, it bridges the gap between technology, instrument design, and learning psychology by demonstrating that AM-driven ergonomic enhancements have a tangible impact on both physical comfort and educational engagement. This interdisciplinary approach opens new avenues for further exploration of AM's role in improving musical training environments.

Second, this study introduces the concept of customization as a key factor in instrument learning. The findings suggest that personalized instrument design can significantly enhance user experience and practice commitment, challenging traditional one-size-fits-all approaches in musical instrument manufacturing. This perspective may encourage future research on how individualized instrument modifications can enhance performance outcomes across different musical traditions.

Third, this study proposes a methodological framework for evaluating instrument design, combining user interviews, and ergonomic testing. This approach provides a structured means for assessing the impact of design modifications on both performance quality and user experience, offering a valuable reference for future studies on musical instrument optimization.

Implications for Future Research and Practice

Despite the positive conclusions drawn from this study, certain limitations remain. First, the research duration was relatively short; future studies could conduct long-term tracking to further investigate the long-term effects of leg rest optimization on performance development and sustained learning interest. Second, the sound quality assessment in this study primarily relied on semi-structured interviews, lacking objective measurement data under laboratory conditions. Future research could incorporate acoustic analysis techniques to conduct precise measurements in controlled environments, yielding more rigorous evaluations of sound quality.

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