Jurnal Sistem Teknik Industri
Journal homepage: https://talenta.usu.ac.id/jsti

User-Centered Redesign of Dental Cheek Retractor Using Quality Function Deployment

Owen Sebastian[*1], Rosnani Ginting[2], Aulia Ishak[3]
[1]*Industrial Engineering Department, Universitas Sumatera Utara, Medan, 20155, Indonesia*
[*]Corresponding Author: owensebastian28945@gmail.com

ARTICLE INFO
Article history:
Received 21 April 2026
Revised 5 June 2026
Accepted 5 June 2026
Available online 8 June 2026

E-ISSN: 2527-9408
P-ISSN: 1411-5247

How to cite:
O. Sebastian, R. Ginting, and A. Ishak, "User-centered redesign of dental cheek retractor using quality function deployment," *J. Sist. Tek. Ind.*, vol. 28, no. 2, pp. 117–124, June 2026.

ABSTRACT
This study aims to redesign the cheek retractor to enhance patient comfort and clinical efficiency, reducing soft-tissue trauma caused by poor fitting and material rigidity in conventional devices. A two-phase Quality Function Deployment (QFD) approach was applied involving ten dentists to identify user needs. Phase I (House of Quality) translated these needs into technical characteristics, while Phase II mapped the prioritized characteristics to critical components for design improvement. The results showed that QFD Phase I prioritized technical specifications such as product weight and mechanical strength, whereas Phase II prioritized the structural material and the width adjustment mechanism. The improved design utilizes durable PC/ABS material capable of repeated sterilization, effectively reducing tissue trauma, increasing comfort, and providing adjustable fitting for various oral anatomies. Overall, this study offers an innovative, QFD-based framework that directly links the voice of the dentist to engineering specifications to develop ergonomic and user-centered medical instruments.
Keyword: *Product Design, Dental Tools, Cheek Retractor, Quality Function Deployment (QFD)*

ABSTRAK
Penelitian ini bertujuan merancang ulang retraktor pipi guna meningkatkan kenyamanan pasien dan efisiensi klinis, serta mengurangi trauma jaringan lunak akibat ketidaksesuaian ukuran dan kekakuan material pada alat konvensional. Pendekatan Quality Function Deployment (QFD) dua fase diterapkan dengan melibatkan 10 dokter gigi untuk mengidentifikasi kebutuhan pengguna. Fase I (House of Quality) digunakan untuk menerjemahkan kebutuhan tersebut menjadi karakteristik teknis, sementara Fase II memetakan karakteristik yang diprioritaskan ke komponen kritis untuk perbaikan desain. Hasil penelitian menunjukkan bahwa pada QFD Fase I, prioritas spesifikasi teknis terletak pada berat produk dan kekuatan mekanis, sedangkan QFD Fase II memprioritaskan komponen material struktur dan mekanisme penyesuaian lebar. Desain yang disempurnakan ini menggunakan material PC/ABS yang tahan lama dan dapat disterilisasi berulang, sehingga efektif mengurangi trauma jaringan, meningkatkan kenyamanan, dan ukurannya dapat disesuaikan dengan berbagai anatomi mulut. Secara keseluruhan, studi ini menawarkan kerangka kerja inovatif berbasis QFD yang menghubungkan langsung masukan dokter gigi dengan spesifikasi teknik untuk mengembangkan instrumen medis yang ergonomis dan berpusat pada pengguna.
Keyword: Perancangan Produk, Alat Dental, Cheek Retractor, Quality Function Deployment (QFD)

http://doi.org/10.32734/register.v27i1.idarticle

1. Introduction

One of the major challenges in dental practice is the inherently limited working space within the oral cavity, where restricted mouth opening and narrow anatomic structures complicate access and visibility to the operative field [1]. Limited intraoral space and suboptimal illumination further hinder instrumentation and can make routine procedures technically demanding [2].

Cheek retractor is an intraoral soft-tissue retraction device designed to hold the lips and cheeks away from the teeth and gingiva, providing an unobstructed view of the dentition and operative field during dental procedures [3]. It is widely used in orthodontic treatment, restorative procedures, and intraoral photography to improve access, visibility, and moisture control, helping maintain a dry field during moisture-sensitive interventions [4].

Complaints about the current cheek retractor indicate a clear need for redesign to improve both functionality and patient comfort. Addressing these shortcomings is essential to better support dentists in delivering effective treatment. The cheek retractor evaluated in this study, produced by PT X, was obtained from an online marketplace, and its detailed configuration is presented in Figure 1.

Figure 1. Cheek Retractor

The cheek retractor evaluated in this study, produced by PT X, was obtained from an online marketplace, and its detailed configuration is presented in Figure 1. The cheek retractor is a single-piece device with specific specifications: it measures 12 × 8.5 × 1 cm and has a weight of 10 grams. It is a C-shaped retractor made from transparent, clear acrylic and is sterilized using an autoclave at temperatures up to 121°C.

Feedback collected using preliminary questionnaires indicated that the most frequent problems were patient discomfort and soft-tissue irritation caused by prolonged retraction and rigid materials [5]. These issues underscore the need for product redesign to enhance comfort and reduce tissue trauma [6]. Therefore, the primary objective of this research is to redesign the conventional cheek retractor to address these specific patient complaints by improving material flexibility and dimensional adaptability [7].

To systematically achieve these improvements, Quality Function Deployment (QFD) was adopted. QFD provides a structured framework to connect customer requirements with technical specifications, enabling prioritization of critical design features and ensuring consumer needs and desires are met [8]. In Phase I of QFD, customer needs are translated into technical characteristics and their relative importance is evaluated [9]. In Phase II, the technical characteristics are further deployed into design requirements, allowing the identification and prioritization of critical parts that must be improved or redesigned [10].

2. Research Methodology

In this study, a purposive sampling method was utilized to distribute preliminary questionnaires to 10 practicing dentists in the Medan Selayang District [11]. The sample size was determined using a nomogram method with a 5% margin of error [12]. The participants were selected to deeply explore clinical issues such as patient discomfort caused by rigid pressure on the oral cavity [13].

2.1. Product Design

Product design is the process of creating and developing ideas into tangible products that meet functional, ergonomic, and aesthetic requirements. It is not limited to the technical aspects of manufacturing but also encompasses user experience, ensuring that products align with customer needs and expectations [14]. According to Akao, effective product design integrates customer requirements into engineering specifications, thereby reducing the gap between what users expect and what manufacturers deliver [15].

2.2. Quality Function Deployment

Quality Function Deployment (QFD) is a structured product development methodology introduced by Akao in 1990, designed to systematically transform customer needs into technical requirements and design solutions [16], [17]. Phase I of Quality Function Deployment (QFD) focuses on translating customer needs into product

characteristics, while Phase II takes these characteristics and translates them into specific module and component specifications, ensuring the design fulfills the technical requirements [17].

2.2.1. QFD Phase I: Product Planning

Phase I of QFD, commonly referred to as the House of Quality (HoQ), is the foundation of the method and focuses on product planning. The main objective is to identify customer requirements (WHATs) and translate them into measurable technical characteristics (HOWs). This ensures that user needs are systematically prioritized and embedded in the design process [16]. The figure below shows the structure of HoQ in QFD, showing framework for translating customer requirements into product technical characteristic.

In the first phase of QFD, several systematic steps are followed to translate customer needs into technical characteristics.

a. Determine Customer Requirements (CR): Customer Requirements are identified through open- and closed-ended questionnaires to capture comprehensive user expectations [18].

b. Determine the Level of Importance of Attribute: Each requirement is then evaluated to determine its relative importance, which reflects the percentage level of priority in product design [19].

c. Define Product Technical Characteristic: Product Technical Characteristics were determined through discussions and interviews [20].

d. Establish relationship between technical characteristics: Determine relationship between each technical characteristic based on mutually supportive or contradictory relationship. The degree of these relationships consist of strong positive relationship, moderate positive relationship, no connection, moderate negative relationship, strong negative relationship [10].

e. Determine level of relationship between Technical Characteristics and Consumer Needs: Relation matrix is used to established the degree of correlation between customer requirement and technical characteristic based on the following rules: 9 shows a strong relationship, 3 indicates a moderate relationship, 1 indicates a weak relationship, 0 indicates no relationship at all [21].

f. Determine Planning Matrix: The planning matrix is developed as a tool to evaluate consumer satisfaction with a product. Its construction also serves to determine the ranking or priority order of consumer needs. The matrix is generated through calculations based on various data sources and involves the following stages [22].

1) Assessing consumer satisfaction levels with the product
2) Determining the improvement ratio for each variable according to its level of importance or expectation
3) Assigning a "sales point" to each consumer need variable
4) Calculating the absolute planning weight for each variable
5) Computing the relative planning weight for each variable

g. Build Phase I House of Quality Matrix: Technical matrix is constructed to evaluate the performance of the House of Quality, including parameters such as technical difficulty, degree of importance, and estimated cost [23].

2.2.2. QFD Phase II: Part Deployment

Phase II of QFD, known as Part Deployment, extends the outcomes of Phase I by linking prioritized technical requirements to specific product components or subsystems. This step determines which parts of the product are most critical in achieving customer satisfaction, thereby guiding material choices, structural design, and detailed specifications [16]. The development process of QFD Phase II consists of several structured steps.

a. Identify the priority technical characteristics (TC) derived from Phase I [10]
b. Determine Critical Part [9]
c. Determine Level of Relationships Between Critical Parts [8]
d. Determine Relationship between Technical Characteristic and Critical Parts [24]
e. Determine Technical Matrix [25]

The technical matrix was established based on QFD Phase II performance indicators: difficulty, importance, and cost.

3. Result and Discussion

This study introduces a novel approach to cheek retractor design by adopting QFD, a technique that has not been applied in this context before. It also systematically addresses user complaints by employing an engineering-based method to solve dentistry-related problems.

3.1. Quality Function Deployment Phase I

The analysis based on QFD Phase I shows that the main targets for improvement are the technical characteristics of product weight, material durability, and mechanical strength. Product weight receives the highest degree of importance 22% with a difficulty level of 4 and an estimated cost of 20, indicating that reducing the overall weight of the cheek retractor is a top priority even though it is relatively difficult and cost-intensive to implement. Mechanical strength is the second-highest priority with degree of importance of 21%, difficulty level of 4 and estimated cost of 20.

The proposed improvement aims to increase material flexibility and mechanical strength without significantly adding to the product weight. This is achieved by replacing the current plastic material of the cheek retractor with a PC/ABS blend, which offers greater toughness and flexural performance while maintaining adequate resistance to clinical loads. By emphasizing these technical features in QFD Phase I, the redesign intends to reduce soft-tissue pressure and patient discomfort while ensuring structural reliability. The focus on material flexibility and mechanical strength is shown in Figure 2.

Customer Requirement	*Customer Importance*	Dimensional Accuracy	Material Flexibility	Material Durability	Mechanical Strength	Product Weight	Biocompatibility	*Improvement Ratio*	*Sales Point*	*Importance Weight*	*Relative Weight*
The material of the cheek retractor is plastic	4	3	9	9	9	9	9	0,7222	1,5	4,3329	21,63
The color of the cheek retractor is transparent	4	0	1	1	0	0	1	0,5738	1,2	2,7543	13,75
The size of the cheek retractor is 13 x 6 x 1 cm	5	9	9	3	3	3	3	0,7971	1	3,9854	19,89
The sterilization method is autoclaving	5	1	1	3	1	0	3	0,8043	1,5	6,0321	30,11
An added function to the cheek retractor is width adjustment	5	9	9	3	9	9	3	0,6106	1,2	2,9311	14,63
Level of Difficulty		3	4	3	4	3	3				
Degree of Importance		17	22	14	21	16	14				
Estimated Cost		15	20	15	20	15	15				

Figure 2. House of Quality (HoQ) Phase I

The House of Quality (HoQ) in Phase 1 translates the Voice of the Customer (VoC) into specific technical characteristics. Based on Figure 2, the highest priority technical requirements are product weight (22%) and mechanical strength (21%). These results indicate that to improve patient comfort, the design must prioritize a lightweight structure without compromising the tool's durability during clinical procedures. Furthermore, the relationship matrix reveals a strong correlation between the material's elasticity and the reduction of soft-tissue trauma, which serves as a foundation for the subsequent design stage.

3.2. Quality Function Deployment Phase II

QFD Phase II analysis indicates that improvement efforts should mainly focus on the width-adjustment mechanism. This mechanism has the highest priority, with a difficulty level of 5, a degree of importance of 35, and an estimated cost of 36, showing that optimizing the adjustment mechanism needs immediate attention.

Based on the identification of critical parts in QFD Phase II, patient complaints of discomfort and pain due to pressure on the oral tissues can be mitigated by prioritizing enhancements to these critial components. In particular, the integration of a ratchet-type width-adjustment mechanism allows the cheek retractor to be gradually opened and securely locked at various positions. This provides more precise control over the retraction force and helps reduce excessive soft-tissue compression [26]. The focus on enchancing width adjustment mechanism is shown in Figure 3.

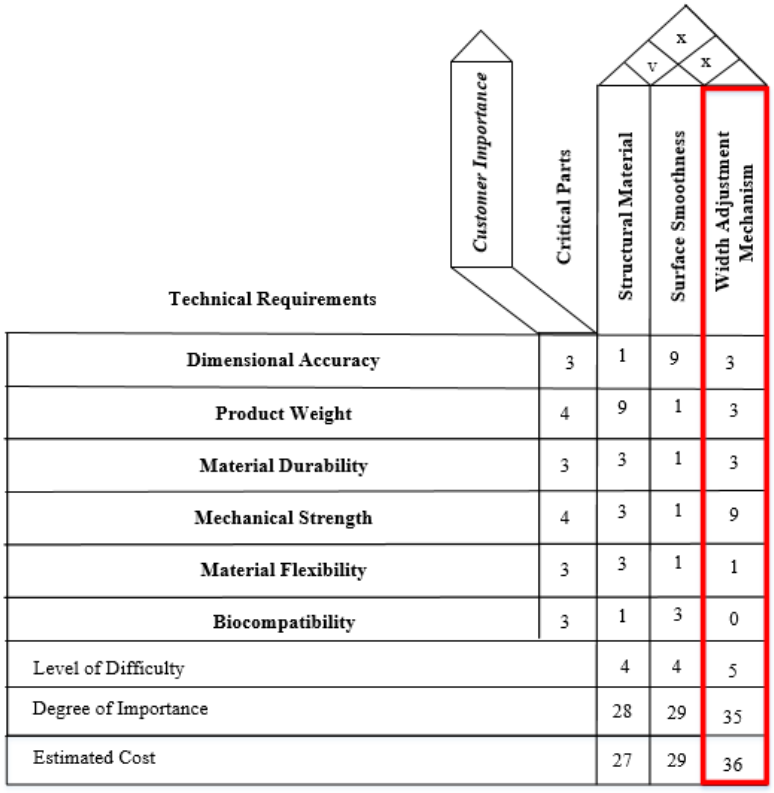

Figure 3. House of Quality (HoQ) Phase II

QFD phase 2 (Part Deployment) focuses on identifying the critical components required to fulfill the technical specifications prioritized in the previous phase. As illustrated in Figure 3, the width adjustment mechanism (ratchet-type system) emerged as the most critical design element with a weight of 35%, followed by the selection of structural material (30%). The integration of a 10-component ratchet mechanism allows for a more personalized fit for varying oral anatomies, addressing the 'one-size-fits-all' limitation of conventional retractors. Additionally, the transition to a PC/ABS blend is strategically prioritized to ensure the device can withstand repeated sterilization cycles while maintaining the necessary flexibility for patient comfort.

By integrating ratchet-type mechanism and transitioning to a flexible PC/ABS blend, the proposed product directly answers the primary customer complaints regarding soft-tissue trauma and discomfort. The adjustable sizing mechanism ensures a personalized fit for varying oral anatomies, effectively eliminating the excessive, static pressure characteristic of conventional 'one-size-fits-all' rigid retractors.

Comparison of the initial and proposed product, are presented in Table 1.

Table 1. Comparison of Initial Product and Proposed Product

Remarks	Product	Image	Specification	Modifications
Mechanism Width Adjustment and Structural Materials	Initial		Size: 12 × 8.5 × 1 cm Weight: 10 g Material: Plastic Polycarbonate (PC)	Apply mechanism width adjustment using mechanism ratchet Replacing PC plastic material with mixture PC and ABS plastic
	Proposed		Size: 13 × 6 × 1 cm Weight: 10 g Material: Mixed Plastic Polycarbonate (PC) and ABS	

4. Conclusions

In conclusion, Phase I QFD identified material flexibility and mechanical strength as the most critical technical characteristics, indicating an urgent need to enhance both comfort and structural reliability of the cheek retractor. The proposed improvement therefore replaces the original polycarbonate body with a PC/ABS blend, which offers better toughness and flexural behavior while maintaining adequate strength under clinical loads. By focusing on these technical characteristics, the redesign aims to decrease soft-tissue pressure and patient discomfort, thereby better satisfying user requirements.

Based on the Phase II QFD analysis, the width-adjustment mechanism was identified as the most critical component, followed by the structural material and surface smoothness. In line with the product improvement strategy, a ratchet-type width-adjustment mechanism was added to enable step-by-step, controlled expansion and secure positioning of the retractor. These modifications together create a cheek retractor that is more comfortable, and clinically stable for intraoral procedures.

This paper contributes a structured, engineering-based framework that directly translates the voice of the dentist into technical specifications to develop ergonomic, user-centered medical instruments. For future research directions, it is recommended to integrate Kansei Engineering to better capture the emotional and psychological responses of patients towards dental tools. Furthermore, determining structural sizing through targeted questionnaires, rather than relying solely on standard anthropometric data, is advised to ensure a more accurate representation of clinical needs. Finally, applying Design for Additive Manufacturing (DfAM) principles is strongly suggested to optimize the prototyping and complex fabrication of the proposed ratchet mechanism

5. Acknowledgements

The author wishes to thank all respondents who participated in this research and all parties who supported the completion of this article.

References

[1] B. Kumar, A. Fernandes, and P. Sandhu, "Restricted mouth opening and its definitive management: A literature review," *Indian Journal of Dental Research*, vol. 29, no. 2, p. 217, 2018, doi: 10.4103/ijdr.IJDR_544_16.

[2] H. Kihara *et al.*, "Accuracy and practicality of intraoral scanner in dentistry: A literature review," *J Prosthodont Res*, vol. 64, no. 2, pp. 109–113, Apr. 2020, doi: 10.1016/j.jpor.2019.07.010.

[3] C. Saadeh, H. Tohme, G. Lawand, N. Khoury, and C. Yared, "Effect of Utilizing Cheek Retractors on Patient Satisfaction and Trueness of Peripheral Borders in Maxillary Digital Scans for Totally Edentulous Patients: An In Vivo Study," *Int J Prosthodont*, pp. 1–23, Mar. 2024, doi: 10.11607/ijp.8895.

[4] L. Sangalli *et al.*, "Effects of remote digital monitoring on oral hygiene of orthodontic patients: a prospective study," *BMC Oral Health*, vol. 21, no. 1, p. 435, Dec. 2021, doi: 10.1186/s12903-021-01793-9.

[5] T. H. A. Bahia, A. R. Idan, and K. R. Athab, "The Effect of Quality Function Deployment (QFD) in Enhancing Customer Satisfaction," *International Journal of Professional Business Review*, vol. 8, no. 1, p. e01156, Jan. 2023, doi: 10.26668/businessreview/2023.v8i1.1156.
[6] D. J. Sharma, K. M. Chauhan, V. Sodani, H. H. Solanki, R. D. Shah, and V. R. Agarwal, "Comparative Evaluation of Ease of Operator and Patient Acceptability Using the Traditional Isolation System vs a New Isolation Tool (Intraoral Cheek and Lip Retractor Mouth Opener Tool)," *Int J Clin Pediatr Dent*, vol. 17, no. 6, pp. 637–640, Aug. 2024, doi: 10.5005/jp-journals-10005-2854.
[7] T. Z. Khattab, M. Y. Hajeer, and H. Farah, "Evaluation of the C-lingual Retractor and the Conventional Lingual Orthodontic Brackets in Terms of Speech Performance and Oral Discomfort: A Randomized Controlled Trial," *Cureus*, Apr. 2022, doi: 10.7759/cureus.23752.
[8] M. Bazarado and Y. Ekawati, "DESIGNING THE ATTRIBUTES OF FOOD PRODUCTS USING QUALITY FUNCTION DEPLOYMENT (QFD) PHASE II," p., 2015, [Online]. Available: https://consensus.app/papers/designing-the-attributes-of-food-products-using-quality-bazarado-ekawati/6223953668c65ee1bec6503324d81671/
[9] R. Ginting, B. Suwandira, and A. Fauzi Malik, "Determination of Technical Requirements and Priority of The Critical Part In The Quality Function Deployment Phase I and Quality Function Deployment Phase II Methods In Product Development : A Literatur Review," *IOP Conf Ser Mater Sci Eng*, vol. 1003, no. 1, p. 012026, Dec. 2020, doi: 10.1088/1757-899X/1003/1/012026.
[10] R. Ginting, A. Ishak, and Widodo, "Prioritizing critical parts of crumb rubber product by using quality function deployment (QFD) phase II : Product design matrix," *IOP Conf Ser Mater Sci Eng*, vol. 505, no. 1, p. 012090, May 2019, doi: 10.1088/1757-899X/505/1/012090.
[11] H. Hong, S. Hahn, H. Kim, and Y. Choi, "Nomogram for sample size calculation in assessing validity of a new method based on a regression line," *Commun Stat Theory Methods*, vol. 52, no. 16, pp. 5900–5909, Aug. 2023, doi: 10.1080/03610926.2021.2023182.
[12] P. Athanasiadou, A. Arhakis, D. Balli, A. E. Zarkadi, K. Arapostathis, and V. Boka, "The impact of radiographic examination timing and gag reflex on dental fear and cooperation in children: a comparative clinical study," *European Archives of Paediatric Dentistry*, vol. 26, no. 2, pp. 375–383, Apr. 2025, doi: 10.1007/s40368-024-00993-5.
[13] B. Gucyetmez Topal, S. B. Falay Civelek, M. Tiras, and T. Yigit, "The prevalence and influencing factors of gag reflex in children aged 7–14 years in the dental setting," *J Oral Rehabil*, vol. 50, no. 5, pp. 376–382, May 2023, doi: 10.1111/joor.13432.
[14] Cohen L, "Quality_Function_Deployment," 2007.
[15] Y. Akao, *Quality Function Deployment*. New York: Productivity Press, 1995. doi: 10.4324/9781003578833.
[16] Y. Akao, *Quality Function Deployment*. New York: Productivity Press, 2024. doi: 10.4324/9781003578833.
[17] J. Hauser and D. Clausing, "House_of_Quality," 1988.
[18] R. Dou, W. Li, and G. Nan, "An integrated approach for dynamic customer requirement identification for product development," *Enterp Inf Syst*, vol. 13, no. 4, pp. 448–466, Apr. 2019, doi: 10.1080/17517575.2018.1526321.
[19] G. S. WASSERMAN, "ON HOW TO PRIORITIZE DESIGN REQUIREMENTS DURING THE QFD PLANNING PROCESS," *IIE Transactions*, vol. 25, no. 3, pp. 59–65, May 1993, doi: 10.1080/07408179308964291.
[20] C. Fajri and Sutrisno, "Perancangan Shelter Bus Mebidang Dengan Menggunakan Quality Function Deployment (QFD)," *Jurnal Sistem Teknik Industri*, vol. 22, no. 1, pp. 77–89, Jan. 2020, doi: 10.32734/jsti.v22i1.3630.
[21] M. Muhammad and M. Fadilla, "PERANCANGAN DESAIN PRODUK ALAT TULIS KANTOR DENGAN MENGGUNAKAN METODE QUALITY FUNCTION DEPLOYMENT," *Jurnal Sistem Teknik Industri*, vol. 20, no. 1, pp. 10–13, Aug. 2018, doi: 10.32734/jsti.v20i1.378.
[22] R. K. Singh, C. C. Elrod, and E. A. Cudney, "Comparative Analysis of Quality Function Deployment Methodologies: A Case Study Analysis," *Quality Management Journal*, vol. 19, no. 1, pp. 7–23, Jan. 2012, doi: 10.1080/10686967.2012.11918524.
[23] C. Plowman, "1 Tailoring Quality Function Deployment for Use in Systems Engineering," *INCOSE International Symposium*, vol. 9, no. 1, pp. 820–827, Jun. 1999, doi: 10.1002/j.2334-5837.1999.tb00244.x.

[24] Y. Zhang, "Green QFD-II: A life cycle approach for environmentally conscious manufacturing by integrating LCA and LCC into QFD matrices," *Int J Prod Res*, vol. 37, no. 5, pp. 1075–1091, Mar. 1999, doi: 10.1080/002075499191418.
[25] J. Huang, L.-X. Mao, H.-C. Liu, and M. Song, "Quality function deployment improvement: A bibliometric analysis and literature review," *Qual Quant*, vol. 56, no. 3, pp. 1347–1366, Jun. 2022, doi: 10.1007/s11135-021-01179-7.
[26] K. Noda, Y. Nakamura, T. Oikawa, S. Shimpo, K. Kogure, and A. Hirashita, "A new idea and method of tooth movement using a ratchet bracket," *The European Journal of Orthodontics*, vol. 29, no. 3, pp. 225–231, Jun. 2007, doi: 10.1093/ejo/cjm002.