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Improvement of Working Volume and Applications of Retractors Used in Surgical Operations

Cerrahi Operasyonlarda Kullanılan Ekartörlerin Çalışma Hacmi ve Uygulamalarının Geliştirilmesi

Akif Cinel[1,a], Huseyin Ipek[2,b,*], Altug Usun[2,c], Kutay Cava[2,d], Mustafa Aslan[2,e]

[1]*Karadeniz Technical University, Faculty of Medicine, Department of Surgery, Trabzon, Turkey.*

[2]*Karadeniz Technical University, Medical Device Design and Manufacturing Application and Research Center, Trabzon, Turkey.*

[*]*Corresponding author e-mail: hipek@ktu.edu.tr*

[a]*https://orcid.org/0000-0001-9479-7222*
[b]*https://orcid.org/0000-0003-0835-2978*
[c]*https://orcid.org/0000-0003-0773-9548*
[d]*https://orcid.org/0000-0002-3438-5418*
[e]*https://orcid.org/0000-0003-2299-8417*

ABSTRACT

Retractor systems are crucial in assisting physicians during surgical operations, ensuring optimal access to the surgical site, holding necessary equipment, and facilitating various procedures such as holding open wounds, stretching tissues, and removing them from the surgery site. Currently, retractors are tailored to specific anatomical regions. For instance, thyroid surgery presents unique challenges due to the gland's location and proximity to vital structures. Accessing the thyroid tissue amid the complexities of the neck region, which includes muscles like sternohyoid, sternothyroid, thyrohyoid, and omohyoid, requires careful retraction for a safe and effective procedure. The success of thyroid surgery relies on distinguishing the thyroid gland from surrounding structures, precisely determining surgical margins, and ensuring a clear view of the surgical field to mitigate potential complications. In this study, two distinct retractor holder designs, versatile for various operations, were developed and evaluated for their working volume, degrees of freedom in design, and applicability in surgical procedures. These designs aim to contribute to improving surgical outcomes, reducing complications, and general advances in the field of surgical instrumentation.

Keywords: Design, Retractor, Surgical operation, Working volume

ÖZET

Ekartör sistemleri, cerrahi operasyonlar sırasında hekime yardımcı olması, cerrahi bölgeye optimum erişimin sağlanması, gerekli ekipmanların bulundurulması, açık yaraların tutulması, dokuların gerilmesi, ameliyat alanından uzaklaştırılması gibi çeşitli işlemlerin kolaylaştırılmasında önemli bir rol oynamaktadır. Şu anda ekartörler belirli anatomik bölgelere göre uyarlanmıştır. Örneğin tiroid cerrahisinde, bezin konumu ve hayati yapılara yakınlığı nedeniyle benzersiz zorluklar içermektedir. Sternohiyoid, sternotiroid, tirohiyoid ve omohyoid gibi kasları içeren boyun bölgesinin karmaşıklıkları arasında tiroit dokusuna erişim, güvenli ve etkili bir prosedür için dikkatli bir şekilde geri çekilmeyi gerektirir. Tiroit cerrahisinin başarısı, tiroit bezinin çevre yapılardan ayırt edilmesine, cerrahi sınırların kesin olarak belirlenmesine ve olası komplikasyonları azaltmak için cerrahi alanın net bir şekilde görülebilmesine bağlıdır. Bu çalışmada, çeşitli operasyonlar için çok amaçlı, iki farklı ekartör tutucu tasarımı geliştirilmiş ve çalışma hacimleri, tasarımdaki serbestlik dereceleri ve cerrahi işlemlerde uygulanabilirlikleri açısından değerlendirilmiştir. Bu tasarımlar ile cerrahi sonuçların iyileştirilmesine, komplikasyonların azaltılmasına ve cerrahi enstrümantasyon alanında genel ilerlemelere katkıda bulunmayı amaçlamaktadır.

Anahtar Kelimeler: Cerrahi operasyon, Çalışma hacmi, Ekartör, Tasarım

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INTRODUCTION

In surgical practices, precision and clarity of anatomical structures are essential for achieving successful outcomes while minimizing complications.[1–3] Retractor systems serve as tools in this pursuit, facilitating optimal exposure of the operative field, securing necessary apparatus, and enabling effective tissue manipulation.[4–6] The intricacies of surgical procedures become particularly pronounced in specific anatomical regions, demanding specialized retractor systems to navigate the complexities. In thyroid surgery, precision is paramount, especially when navigating the intricacies surrounding the strap muscles—sternohyoid, sternothyroid, thyrohyoid, and omohyoid. Accessing the thyroid tissue safely and effectively demands not only accuracy but also a sophisticated strategy for retraction. This involves differentiating the gland from surrounding vital structures, defining surgical margins, and ensuring optimal visualization.[7,8]

Tiwari et al. compared the performance of the suction retractor in 300 cases of mesioangular impactions.[9] with a focus on achieving good visualization and a bloodless field for surgery. Recognizing the need for an innovative tool, they purposed a retractor, with modifications, shows potential to enhance suction, retraction, visualization, reduce surgery time, and improve post-operative comfort for both surgeons and patients. Espinosa et al. pointed out the importance of imaging accuracy of breast conserving surgery treatment option for early-stage breast cancer.[10] This study introduces a breast retraction phantom and deformation modeling method to explore the potential of compensating for these deformations during BCS image guidance. Using CT scans of silicone breast phantoms with embedded beads, a sparse-data registration technique was employed, demonstrating promising accuracy. Similarly, the application of breast surgery, a cornerstone in treating both benign and malignant conditions, requires a nuanced understanding of breast tissue and its relationship with adjacent structures.[11,12] In the context of breast cancer surgery, the comprehensive removal of lymph nodes in the armpit is paramount for effective treatment. This necessitates sophisticated retraction techniques to unveil adjacent muscles and nerves, ultimately optimizing the surgical field for reduced complications. Modern surgical practice prioritizes cosmetic concerns, steering surgeries towards minimally invasive procedures. This paradigm shift is evident in thyroid and breast surgeries, where the emphasis lies on smaller incisions and clear visualization of the surgical site. The success of these procedures hinges on the ability to visualize anatomical and pathological structures precisely.

Currently the types of retractors are in a diverse range, featuring handheld options like the Richardson retractor, US Army retractor, farabeuf retractor, and Lahey thyroid retractor, alongside self-retaining alternatives such as Jolls thyroid retractor, Beckman thyroid retractor, and MASTR retractor.[13–16] Each caters to specific surgical needs, reflecting the requirements of diverse procedures. A well-designed retractor system must prioritize both its applicability and size. The design must allow freedom of movement for the surgeon and operators without imposing restrictions. Moreover, the retractor system should enhance visibility for the operators, promoting effective surgical applications and minimizing complications.[17–19]

Roca et al. designed an expandable chamber retractor to reduce the risk in the neurosurgical interventions for the treatment of complex pathologies in high risk brain areas. [20] Utilization of this retractor reduces the pressure on the brain to avoid complications. Additionally, validation of the design was proved in animal tests and blind comparisons.

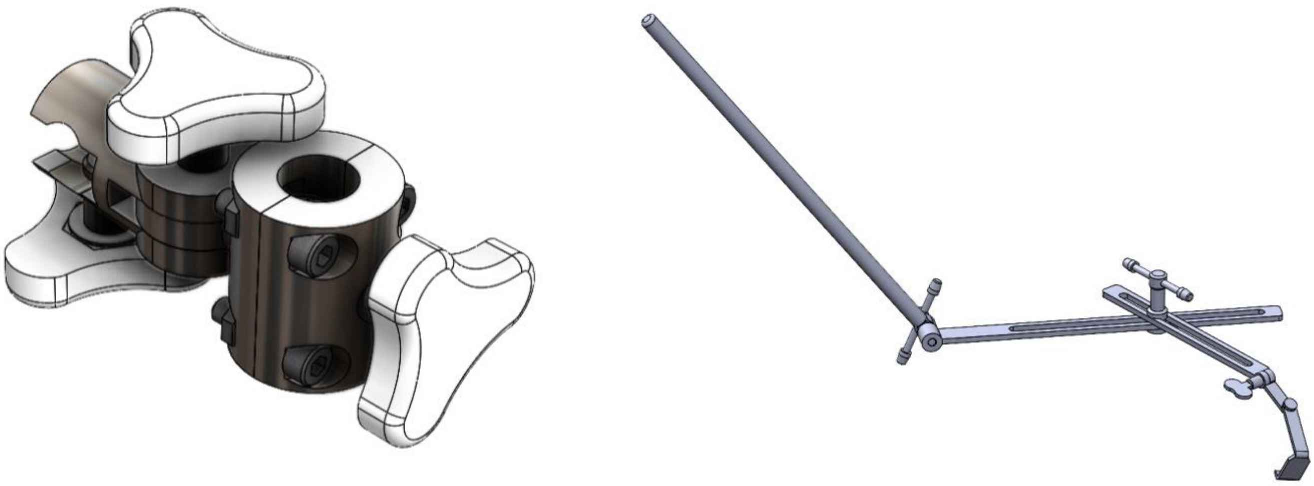
The success of the designed retractors in the literature shown that development of the novel retractors can reduce risks and complications in various fields or surgeries. Therefore, in this study, we designed novel retraction systems with the versatility and efficiency of retraction across various surgical scenarios instead of being operation-specific. Traditional retractors typically employ a single-piece element, constraining retraction to two axes depending on the application of the retractor.[21,22] In contrast, our design features a retractor system comprising three interconnected parts, allowing simultaneous retraction in three axes. This revolutionary advancement provides a dynamic and adaptable tool for surgeons seeking greater precision. Furthermore, our system introduces separator elements, offering the flexibility to deploy them bilaterally or unilaterally. This adaptability allows surgeons to tailor the configuration for optimal visualization of the anatomical region requiring retraction. Its adaptability extends beyond specific surgeries and can be used in various operations and medical applications. Through this innovation, we aspire to contribute significantly to the evolution of surgical tools, improving efficiency, precision, and improved patient outcomes.

METHODS

The retractor designs in this study were modeled in 3D using Solidworks design software. The primary focus of both retractor systems was to increase the working volume and degrees of freedom. In pursuit of this goal, the design ensured that the retractor systems remained compact enough not to impede the application area or the surgeon's field of vision. Additionally, the retractor systems were engineered to balance strength and compactness, which is essential for tasks such as pulling tissues or supporting apparatus. This equilibrium was achieved by selecting a midpoint that optimally combined strength and size. The designed components were subsequently manufactured using CNC machining, employing stainless steel as the material to mitigate contamination. For the plastic parts of the retractors, Fused Deposition Modeling (FDM) was employed. PLA was selected as the print material due to its biocompatible and easily sterilizable nature.[23,24] A 100% infill ratio was chosen for all the printed parts to ensure durability and high mechanical properties. Other printing parameters are 210°C nozzle temperature, 60°C heated bed temperature, 60 mm/s printing speed, and 0.2 mm layer thickness. The models were sliced using Ultimaker Cura, considering the specified parameters.

RESULTS

In this study, two design prototypes were developed for retractors intended for versatile use across various surgical procedures. These retractors feature a higher working volume and a high degree of freedom to simplify surgical complexities and minimize the need for additional operators. Importantly, these designs ensure unobstructed vision and unrestricted movement during operations. These two designs are shown in Figure 1. The design shown in Figure 1a will be referred to as the coupling-type retractor. In contrast, the design featured in Figure 1b will be referred to as the telescopic retractor for clarity and distinction throughout this study.



(a) (b)

Figure 1. The 3D models of the designed retractors: a) coupling-type retractor and b) telescopic retractor

The coupling-type retractor

The coupling-type retractor is a compact device designed to hold various surgical instruments securely. Typically, it is configured to attach to the side of the patient's bed while firmly supporting an apparatus that aids in surgical procedures. This design consists of three main bodies, three tightening screws, and assembly screws shown in Figure 2. The main bodies on the sides of the retractor are designed to be connected to fixed locations or apparatus needed in surgical applications. The assembly screws can be removed to facilitate the connection of the retractor to a fixed location, such as the sides of a patient's bed. This allows for the disassembly of the parts, enabling the establishment of the desired connections. Additionally, these coupling retractors and shafts can be used in series to extend the reach of the retractor and increase its application possibilities.

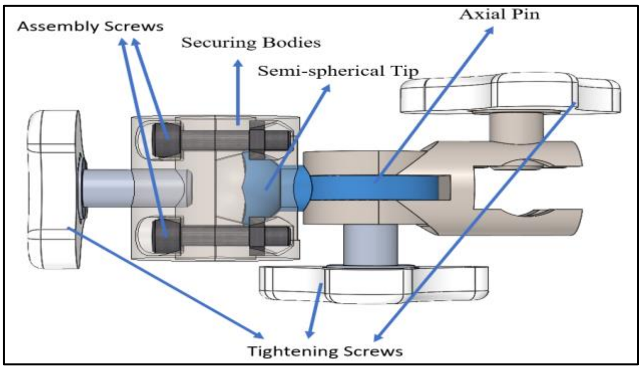


Figure 2. Parts of the coupling-type retractors

The central, blue-colored main body component in the middle of the design functions as a connecting element, facilitating rotations of the retractor design in various axes. This feature enables the connected apparatus to reach any point within the surgical application area. The combination of multiple connections and degrees of freedom for rotation enhances the versatility of this retractor despite its compact size. This small-sized retractor can be positioned near the patient's bed, efficiently holding various pieces of equipment over the application area without occupying additional space.

As illustrated in the figure, three tightening screws are incorporated into the design. The rotation point of these screws is designed to be larger for better force application and handling. Each of these screws can be tightened to secure the corresponding movement and rotation along these axes. These rotation axes and the movement capability of the retractor are shown in Figure 3. As seen from the figure, the retractor allows a 360-degree rotation on the X axis, 180-degree rotation on the Y axis, 360-degree rotation on the Z axis, and unrestricted movement along each axis, limited only by the length of the apparatus or connected shafts.

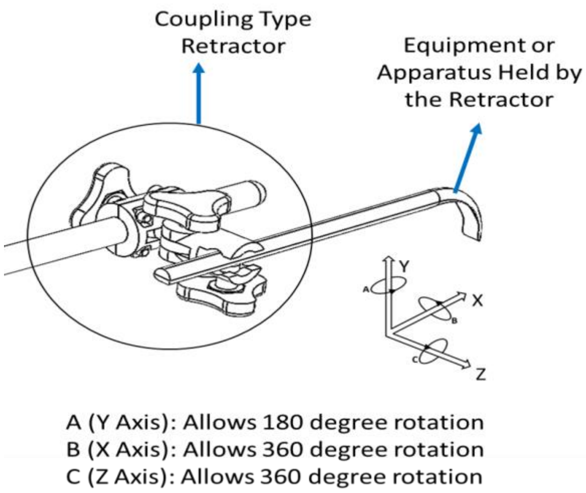


Figure 3. Degrees of freedom and the application on the coupling-type retractor

When summarized, the advantages of this retractor can be listed as follows:

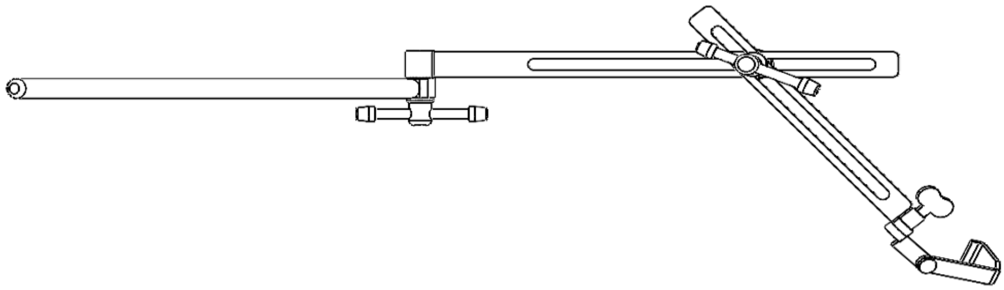
- The primary objective of this retractor is to achieve labor savings through its fixability feature, eliminating the need for an additional person to operate the retractor manually.
- In traditional retractor systems currently in use, the separator element typically comprises a single piece, allowing retraction in only two axes at most.[25–27] Our innovation involves separator elements consisting of three interconnected parts joined with connection bolts, enabling simultaneous retraction in three axes.
- The separator elements can be utilized on both the right and left sides concurrently, as well as on a single side, providing the flexibility to configure the retractor system for optimal visualization of the anatomical area requiring retraction.
- Another goal of the system described in the invention is to grant freedom of movement to the surgeon by reducing instrument density in the surgical field, accomplished through the retractor carrier body featuring an approximately semicircular opening.
- The application scope of the retractor developed in this invention is not confined to a singular operation; it can be employed across various surgeries and applications.

The telescopic retractor

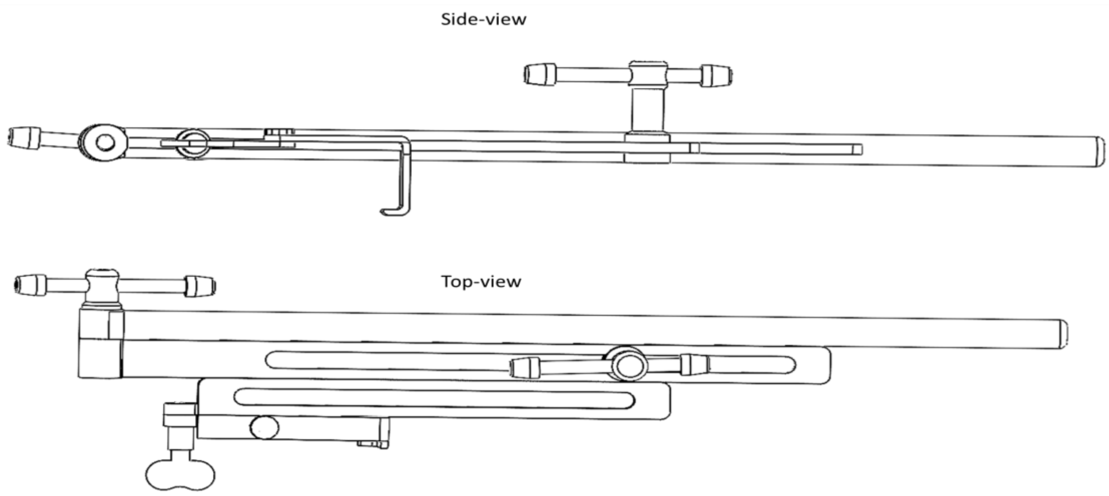
The detailed design of the telescopic retractor developed in this study is presented in Figure 4. Similar to the coupling-type retractor, the telescopic retractor is equipped with tightening screws, which serve to restrict rotation and movement along the corresponding axis. In contrast, this retractor features a larger body, providing an expanded working volume and increased reach for the apparatus it supports. Furthermore, a retractable design was incorporated into this retractor for convenient handling before and after the surgical procedure. The telescopic retractor can be folded to fit into a sterilization bag, facilitating ease of handling and storage.

For example, in the application of the telescopic retractor, a hook-shaped apparatus is currently illustrated at the end of the retractor. One side of the retractor can be secured to the patient's bed or any sturdy surface. Then, the pulling hook can be positioned on the application area where the skin and other tissues need to be held apart, leveraging the rotational freedom of the junctions and the high working volume of the retractor.

Additionally, as depicted in the figure, a sliding part can function as a pulling mechanism in this application for holding the skin and connected tissues. Once the hook end of the retractor is appropriately positioned, all tightening screws, except those on the sliding part, can be secured. Subsequently, the sliding body can be pulled to separate the skin and fixed at the desired location using the tightening screw on the sliding body part.



(a)



(b)

Figure 4. The design of the telescopic retractor, a) open form and b) folded form

Surgical equipment is critical in various surgical positions and configurations to facilitate proper procedures. Surgeons or assistants need to have the flexibility to maneuver retractors directly in different configurations without obstructing the surgical field. These retractors should also offer protection against potential obstacles like medical imaging systems, operating room lighting, and other surgical instruments. The ideal surgical retractor is characterized by stability, ease of control, and the ability to undergo position changes.

The primary objective of this telescopic retractor is to provide labor savings through its fixability feature, reducing the need for an additional person to operate the retractor. In contrast to classical retractor systems, where the separator element is typically a single piece, our invention employs separator elements consisting of three parts joined with connection bolts, which allows the retractor system to execute retraction in three axes simultaneously. Additionally, high working volume and degrees of freedom help the challenge of patient positioning align with the retractor system. Recognizing the need for a bearing/sliding retractor system, this development aims to enhance adaptability and precision in surgical procedures. Similar to the coupling-type retractor, the telescopic retractor developed in this study demonstrates versatility in its applicability across diverse surgical procedures and scenarios.

Manufacturing of the retractors

The designs prepared in this study are manufactured using additive manufacturing and CNC machining. This manufacturing step was crucial within the study, serving to assess the practicality of the designed concepts and validate their feasibility. The manufactured parts are presented in Figure 5.

As depicted in Figure 5a, the coupling-type retractor was manufactured with traditional manufacturing methods. The choice of stainless steel as the production material aimed to ensure sterilizable and corrosion-resistant components. The resultant retractor demonstrated the anticipated high degree of freedom in rotations and unhindered directional movement. Upon fastening the tightening screws, the retractor's parts exhibited fixed movement and rotation, with the ability to withstand substantial force. This successful production validated its applicability in real-world surgical scenarios.

The telescopic retractor, on the other hand, is shown in Figure 5b; in manufacturing the telescopic retractor, FDM technology was employed. This chosen manufacturing method was aimed at producing a functional prototype to demonstrate the capability and mechanism of the retractors. Feature sizes and the material of the retractor need to be optimized based on the required forces, which, in turn, depend on the material being held with it. The telescopic retractor, designed with the ability to extend or fold for an exceptionally high working volume, aligned seamlessly with the intended functionality during the manufacturing phase. Additionally, the retraction process can help the retractor fit within a sterilization bag or make the retractor easier to store. Leveraging the sliding mechanism, the retractor could selectively apply force in the desired direction, offering potential benefits in minimizing tissue damage during surgical applications.

(a) (b)

Figure 5. The manufactured parts of the retractor designs: a) coupling-type and b) telescopic retractor

DISCUSSIONS

Coupling-type retractors

The existing ejectors currently used in the market, as well as those for which patent processes have been completed, have been discussed in relation to the conducted studies. In Figure 1, the ABCD ejector is provided.

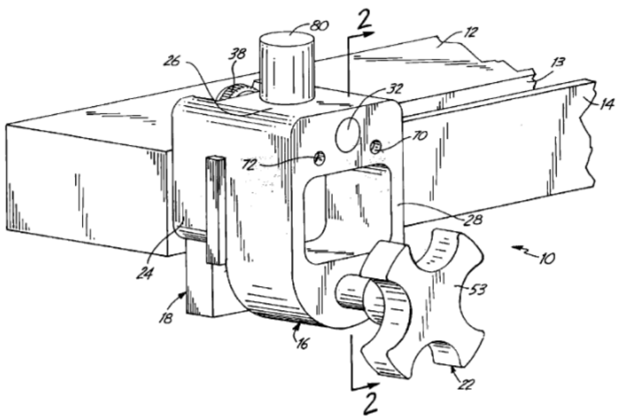


Figure 6. US2004073091A1 numbered patent.

The discussion involves a compression device that secures the ejector support attachment to a surgical table with a side rail. As seen in the above diagram, the ejector system is fixed onto the rail of the bed. This allows the ejector system to be moved along the length of the bed. In this study, an axial pin is incorporated into a structure that includes a semi-spherical tip, allowing for rotation at specific angles until it reaches the desired angle according to the user's needs. The axial pin and the semi-spherical tip are placed between securing bodies and become fixed by attaching these two parts to each other. The semi-spherical part of the tip remains between these two parts. When the first securing body comes together with the second securing body, a gap is created that enables the movement of the semi-spherical tip towards the ejector holder. Thanks to this gap, the semi-spherical tip can be positioned within the area formed between the securing bodies and can rotate around its axis 360° degrees.

In another study with patent number US3810462A, a self-retaining surgical retractor with an adapted retractor holder designed to be attached to the side rail of the operating table is discussed. The visual representation of this retractor is provided in Figure 7.

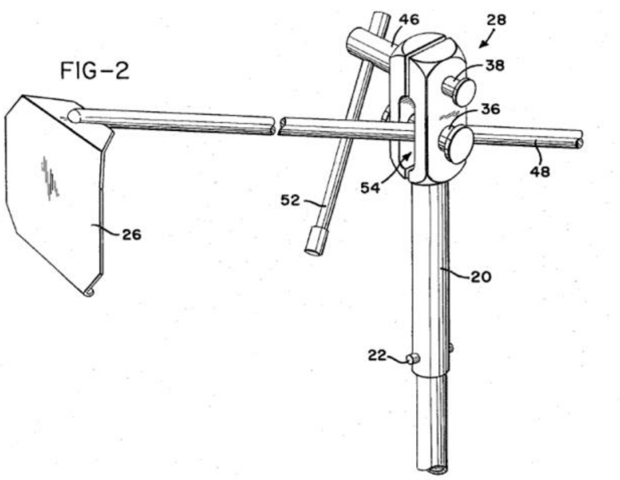


Figure 7. US3810462A numbered patent.

In the presented study, an axial pin is part of a structure that includes a semi-spherical tip, allowing for rotation at specific angles until it reaches the desired angle according to the user's needs. The mentioned axial pin and the semi-spherical tip are placed between securing bodies and become fixed by attaching these two parts to each other. The semi-spherical part of the tip remains between these two parts. When the securing bodies come together, a gap is created, enabling the movement of the semi-spherical tip towards the ejector holder. This gap allows the semi-spherical tip to be positioned within the area formed between the securing bodies and can rotate around its axis 360° degrees, providing the user with ample freedom of movement.

Telescopic retractor

When examining telescopic retractor systems, it is observed that some systems are currently in use. Examples of these systems are provided in Figures 8 and 9.

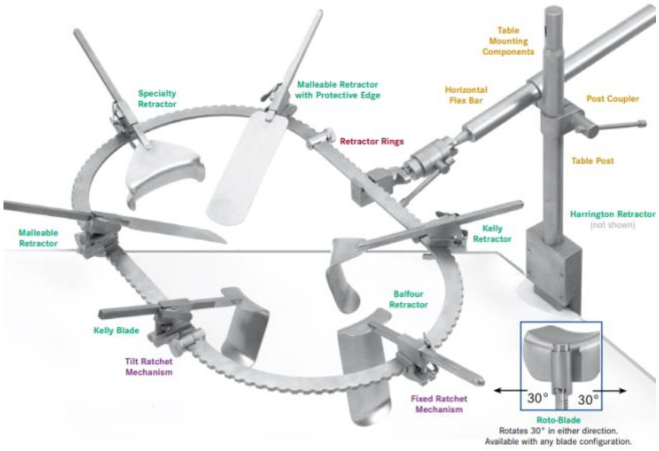


Figure 8. A retractor system[28]

The ability for the surgeon or assistant surgeon to directly manipulate retractors in various configurations is desired. Additionally, the surgical retractors used to achieve this position and configuration should not obstruct the surgeon's field, and they should be capable of preserving the surgical field from obstacles such as medical imaging systems, operating room lighting systems, and other surgical instruments. The surgical retractor should be stable, easily controllable, and capable of facilitating position changes effortlessly. The telescopic retractor presented in this study is designed to meet the mentioned criteria.

Figure 9. Another retractor system[29]

The system specifications provided in Figure 9 are designed for bariatric surgical procedures and tailored to hook-shaped retractors.

This study presents the fixation feature, adjustable configuration, adaptability to patient positioning and versatile application benefits provided by the designed retractor:

- The retractor can be fixed, allowing for workforce savings when the person using the retractor is reduced manually. In many currently used retractor systems, either specialized systems are used based on the type of surgery, or these systems generally consist of a single piece. Therefore, retraction can be performed in at most two axes. In the designed retractor in this study, the retractors are composed of three parts connected to each other with a connecting bolt. This feature enables the retractor system to achieve retraction simultaneously in three axes, offering greater flexibility. Moreover, the system can be used unilaterally or bilaterally simultaneously.
- The retractors can be configured to best display the anatomical region requiring retraction. This adjustable configuration enhances the effectiveness of retraction.
- The retractor system must be positioned appropriately according to the patient's condition. To mitigate placement issues, the development of a bed-mounted/slide system for the retractor system is considered a necessity.
- The designed retractor is not limited to a single type of surgery; it can be utilized in various surgical procedures and applications.

In summary, the developed retractor in this study offers advantages such as workforce savings, enhanced flexibility in retraction, adaptability to different surgeries, and improved patient positioning by introducing innovative design features.

CONCLUSIONS

In response to the surgical demands, this study introduces two novel retraction systems designed to be used in diverse surgical scenarios, contrary to the traditional retractors, which are operation-specific. Our designs enable simultaneous retraction in three axes, offering dynamic adaptability and significantly enhancing precision for surgeons while remaining versatile.

The coupling-type retractor introduced in this study represents a compact and versatile device designed to hold various surgical instruments securely. The incorporation of three interconnected main bodies, assembly screws, and tightening screws enables rotations in various axes for optimal reach within the surgical application area. The retractor's advantages include labor savings, achieved through its fixability feature, and enhanced freedom of movement for surgeons. The separator elements enable simultaneous retraction in three axes, offering flexibility in configuration and broadening its application scope across various surgeries.

On the other hand, the telescopic retractor shares the adaptability features of the coupling-type retractor but emphasizes increased working volume and reach. The retractable design adds convenience for handling before and after surgical procedures. Notably, this retractor addresses challenges in patient positioning, providing labor savings, and maintaining high working volume and degrees of freedom. The telescopic retractor, like its counterpart, demonstrates versatility in its applicability across diverse surgical scenarios.

These innovative retractor designs, the coupling-type and telescopic, offer significant contributions to the field of surgical tools. Their multifaceted capabilities, fixability, and adaptability promise improved efficiency, precision, and, ultimately, enhanced patient outcomes. As the medical community continues to evolve towards more sophisticated and minimally invasive surgical approaches, these retractors stand as valuable additions, meeting the demands of modern surgical practice.

Acknowledgement

The designs developed in this study have been applied for patent protection with the patent number 2022/016858. The patent application process was facilitated with the assistance of the Technology Transfer Application Research Center at Karadeniz Technical University.

Authorship contribution statement

Concept and design: AC, HI.

Acquisition of data: HI, AU, KC.

Analysis and interpretation of data: AC, MA, HI, AU, KC.

Drafting of the manuscript: AC, MA, HI, AU.

Critical revision of the manuscript for important intellectual content: AC, MA, HI, AU, KC.

Statistical analysis: HI, AU, KC.

Supervision: AC, MA.

Declaration of competing interest

None of the authors have potential conflicts of interest to be disclosed.

Ethical approval

Ethical approval is not necessary for his article.

Availability of data and materials

All data generated or analyzed during this study are included in this published article.

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