Review

Technical Aspects of Breast Compression in Mammography: Patient Comfort and Impact on Image Quality

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Abstract:
Breast cancer is one of the most common malignancies among women worldwide. Mammography is the primary imaging modality for early detection of malignant breast changes and plays a crucial role in reducing breast cancer mortality. Breast compression is an essential component of mammography, significantly affecting image quality, radiation dose, and patient comfort. Adequate compression reduces breast thickness, minimises tissue overlap and motion, and improves image contrast. However, it may also cause discomfort or pain, which can negatively affect patient adherence to screening programmes. This review summarises the technical aspects of breast compression in mammography and discusses its impact on image quality and patient-reported comfort. A narrative review of relevant literature was conducted, focusing on breast anatomy, compression techniques, image quality parameters, and patient experience. The findings suggest that optimal compression represents a balance between technical image optimisation and patient-centred care, highlighting the vital role of radiographers in obtaining diagnostically adequate images while minimising patient discomfort.

Keywords: Mammography, Breast Compression, Image Quality, Patient Comfort, Radiographer, Breast Anatomy

1. Introduction

Breast cancer remains one of the most common malignancies among women worldwide. According to the World Health Organization (WHO), approximately 2.3 million women were diagnosed with breast cancer globally in 2022. In Slovenia, 1502 female and 8 male patients were diagnosed with breast cancer in the same year, highlighting the significant national burden of the disease (Institute of Oncology Ljubljana). Breast cancer, therefore, represents a major public health challenge across diverse healthcare systems (Wilkinson & Gathani, 2022).

Mammography is the standard imaging modality for early detection of malignant breast pathology and represents a crucial component of breast cancer screening and diagnosis. Its widespread implementation has contributed significantly to reductions in breast cancer mortality (Loizidou et al., 2023). The diagnostic performance of mammography depends not only on advanced imaging technology but also on optimal image acquisition techniques, which must be carefully optimised while considering patient comfort (Ding et al., 2024).

Breast compression is a fundamental component of mammographic imaging, as it reduces breast thickness, limits tissue superimposition, and minimises motion blur, thereby improving image quality and lesion detectability (Fico et al., 2023). In addition, adequate compression contributes to radiation dose optimisation by reducing the required exposure parameters. Despite these technical benefits, breast compression is frequently associated with discomfort or pain, which may negatively affect patient experience and adherence to breast cancer screening programmes (Serwan et al., 2020).

The anatomical structure of the breast, including the proportion and distribution of glandular, adipose, and connective tissue, plays a significant role in the breast's response to compression. Variations in breast size, tissue composition, and elasticity lead to differences in compression outcomes and patient perceptions of pain, underscoring the importance of individualised compression techniques (Moshina et al., 2020).

Patient-reported discomfort during mammography is a multifactorial phenomenon influenced by physical, psychological, and technical factors, such as compression force, communication with the radiographer, and previous mammography experiences. Achieving patient comfort while maintaining diagnostically adequate image quality remains a continuous challenge in clinical practice (Akansel et al., 2020).

The aim of this review is to present the technical aspects of breast compression in mammography, with particular focus on its influence on image quality and patient comfort, and to highlight the role of radiographers in achieving an optimal balance between diagnostic efficacy and patient-centred care.

2. Design of the Review

A narrative literature review was conducted to summarise current knowledge on the technical aspects of breast compression in mammography, with particular emphasis on patient comfort and image quality. Relevant publications from 2004 to 2025 were considered, reflecting both foundational and contemporary research in mammographic imaging and breast compression techniques.

The review focused on studies that described or evaluated the principles and implementation of breast compression in mammography, its impact on image quality parameters, radiation dose optimisation, and patient-reported discomfort or pain. Literature addressing breast anatomy and tissue composition in relation to compression, as well as the role of radiographers in image acquisition and patient communication, was also included.

Publications written in English were primarily included to ensure consistency and accessibility of scientific sources. The reviewed literature encompassed a wide range of sources, including peer-reviewed scientific articles, review papers, professional guidelines, and academic textbooks. Peer-reviewed original studies provided evidence-based insights into technical and patient-related aspects of breast compression, while review articles contributed to a broader synthesis of existing research.

Professional guidelines and recommendations from international and European organisations, such as those related to mammographic quality assurance and breast imaging practice, were included to reflect standardised clinical approaches.

Foundational anatomical and technical knowledge was supplemented by academic textbooks and reference materials relevant to breast anatomy, mammographic techniques, and radiologic technology.

3. Basic anatomy of the breast

Understanding breast anatomy is fundamental to mammography, particularly in the application of breast compression. Knowledge of the structural components of the breast, including glandular, fibrous, and adipose tissues, as well as supporting ligaments, vascular structures, and nerves, enables radiographers to apply compression in a way that optimizes image quality while minimizing patient discomfort. Proper anatomical knowledge also supports effective positioning, inclusion of all relevant breast tissue, and appropriate distribution of compression force, all of which directly affect image clarity, radiation dose and diagnostic accuracy (Stines & Tristant, 2005).

The adult female breast lies between the second and sixth or seventh ribs. Its base extends medially from the sternal border to the midaxillary line laterally and is surrounded by the superficial and deep fascia of the chest wall. Approximately two-thirds of the breast lie anterior to the pectoralis major muscle, with the remaining portion over the serratus anterior muscle. The upper outer quadrant extends into the axilla as the axillary tail of Spence, an important region during mammographic imaging (McGuire, 2019). The male breast is located at the level of the fourth intercostal space along the midclavicular line. Its glandular component generally does not develop, so the organ is rudimentary. Additionally, the adipose tissue is scarce (Jesinger, 2014).

The breast consists of several distinct tissue layers. The skin forms the most superficial layer. The dermis merges with the superficial fascia, a layer just beneath the skin, which is continuous with the superficial abdominal and cervical fascia. Together with the deep fascia, it envelops the breast parenchyma. This tissue comprises three main tissue types: glandular epithelium, fibrous stroma with supporting structures, and fat (De Benedetto et al., 2016).

Glandular tissue comprises approximately 10-15 % of the female breast and is organized into 15 to 20 lobes. Each lobe is subdivided into lobules, which contain terminal ductal lobular units (TDLUs). These structures are responsible for milk production and are clinically significant, as most malignancies originate within them. The ducts converge towards the nipple where they form lactiferous sinuses beneath the nipple areola complex. The nipple is located at the apex of the breast and is the site where the lactiferous ducts open. It is surrounded by a pigmented area of skin known as the areola (Bazira, 2024).

The fibrous stroma and supporting structures are most referred to as the suspensory ligaments of Cooper. These are fibrous bands of connective tissue that traverse the breast and insert into the dermis. The remainder of the breast is composed of adipose tissue, the proportion of which increases with age and is most prominent in the postmenopausal breast. Variations in the relative amounts of glandular and fatty tissue influence mammographic appearance and the effectiveness of breast compression (McGuire, 2019).

4. Basic aspects of mammography

Mammography is a specialised radiographic imaging technique for the early detection, diagnosis, and evaluation of breast disease. It uses low-energy X-rays to produce high-resolution images, allowing the identification of subtle anatomical details not detectable by clinical examination alone. The effectiveness of mammography depends on a combination of technical factors, including equipment, imaging parameters, patient positioning, and the application of proper breast compression (Arjmandi et al., 2025).

A mammograph is a device specialised for medical imaging of the breast. Its structure differs from that of a basic X-ray imaging machine and consists of an X-ray tube, tube port, filter, collimator, compression paddle, grid, X-ray detector, and automatic exposure meters. The distance between the source and the image is about 65 cm, resulting in a field of view measuring 24 × 30 cm. Another important aspect of the mammograph is the use of the heel effect (Fico et al., 2023). This phenomenon involves variation in beam intensity along the cathode-to-anode direction. As one moves from the cathode towards the anode, the intensity of the radiation beam reaching the detector decreases. The anatomy of the breast also shows a decreasing trend in thickness, so the device is designed to position the patient on the side of the central axis (Kusk et al., 2021).

A motorised compression plate, which is part of a mammograph, is generally made of polycarbonate. During mammography, the breast is compressed using a compression paddle to achieve optimal image quality by reducing breast thickness. Compression enables a lower radiation dose, improves image contrast by minimising scatter radiation, and reduces motion blur by limiting breast movement during image acquisition (Hong, 2019). However, compression is also the main source of discomfort or pain during the examination. Therefore, achieving a balance between adequate compression and patient comfort is a critical technical and professional responsibility of the radiographer (Myklebust et al., 2009).

5. Breast compression in mammography

Breast compression plays a crucial role in mammography as it helps reduce breast thickness (Poulos & McLean, 2004). Compression and the resulting reduction in thickness improve image quality by reducing tissue superposition and breast radiation dose. Consequently, there is less scattered radiation and higher image contrast (Agius & Naylor, 2018). The use of a compression paddle keeps the breast in a fixed position, which improves the image by reducing the risk of motion artefacts and image blurring (Holland et al., 2017). Insufficient compression can negatively impact image quality and lead to improper lesion detection and misdiagnosis (Agius & Naylor, 2018).

The degree of compression applied determines how much breast thickness is reduced from its natural to the compressed state. This reduction directly affects the ability to optimize image clarity and minimize radiation exposure (Poulos & McLean, 2004). Mammography devices measure and display the compression force applied by the compression paddle to the breast during the imaging procedure. However, the pressure defined as the compression force divided by the contact area between the breast and the compression paddle determines how much tissue is compressed (Holland et al., 2017).

In clinical practice, compression is typically applied according to criteria, such as ensuring the breast is firm at the sides, observing skin blanching, or applying strong pressure. However, the level of compression that can be achieved is often limited by the discomfort or pain experienced by the patient (Poulos & McLean, 2004). Currently, there are no standardized guidelines defining the optimal level of breast compression. Modern mammography systems measure compression force, but this parameter does not account for breast size. The lack of standardization results in a wide and inconsistent range of applied forces, which can sometimes be unnecessarily high (Arenas et al., 2022).

Consequently, most imaging centres do not specify a target compression force to be used during the imaging procedure, but most recommend a range and a maximum that can be used (Nightingale et al., 2015). The European Commission recommends that the breast is compressed using a force just below the patient's pain threshold or to the machine's maximum setting, not exceeding 200 N (Dustler et al., 2012). Agius and Naylor (2018) found that radiographers usually use the numerical scale as a reference to ensure sufficient compression is applied to the breast. This is usually within the accepted range of 60 N to 160 N, with the target compression force being 100 N (Agius & Naylor, 2018).

The standard imaging protocol involves the radiographer applying compression force to reduce breast thickness. An alternative protocol is self-compression, in which the patient controls the final stage of breast compression (Alukic et al., 2021). Louro et al. (2022) found that technical indicators were similar for both the standard compression and self-compression examinations, except for compression force, which was significantly higher with self-compression. The results also indicated that patients might prefer the self-compression method over the standard compression examination, even though the reported discomfort was similar (Louro et al., 2022).

6. Image quality

Compression is essential in mammography because it reduces breast thickness and radiation dose while increasing image quality. It also makes small details and tissue changes more visible, which is important for mammography images (Poulos & McLean, 2004). Image quality is improved in several ways, as described in the following section.

Reduction of geometrical blur – Geometrical blur occurs when small details are far from the detector and breast tissue can move during examination. Compression reduces blur by decreasing breast tissue thickness and moving structures closer to the detector, minimising the object-to-detector distance and flattening the breast. This results in a clearer and more diagnostically useful mammographic image without geometric blurring (Fico et al., 2023).

Increase in spatial resolution – Spatial resolution is the ability to distinguish small, closely spaced structures and details in an image. Compression increases spatial resolution by reducing breast thickness and bringing tissue closer to the detector. By flattening tissue layers, overlap and magnification differences are minimised. Compression also limits patient and breast tissue movement, allowing microcalcifications and fine tissue details to be seen clearly (Fico et al., 2023).

Reduction in radiation dose – Compression makes the tissue thinner, reducing the amount of X-ray beams required to penetrate the breast. It also makes the tissue more uniform, so exposure is consistent across the entire breast. Because of the thinner tissue and limited lateral spread of X-rays, scattered radiation is decreased (Fico et al., 2023).

Limiting patient movement – Limiting patient movement during examination is important for ensuring good image quality that is diagnostically useful. Compression helps stabilise the breast, preventing movement, and improves image clarity by reducing motion and producing sharper edges of lesions and microcalcifications (Fico et al., 2023).

Visibility of fine details – Breast compression enhances the visibility of fine details by limiting patient movement, reducing tissue overlap, flattening tissue layers, decreasing breast thickness, and reducing scatter. These effects allow microcalcifications and subtle lesions to be seen more clearly, improving diagnostic accuracy and early cancer detection (Fico et al., 2023).

Improving image uniformity and signal-to-noise ratio – Breast compression enhances image uniformity and signal-to-noise ratio (SNR) across the entire breast. Flattening the tissue makes it more even throughout the breast, allowing X-rays to penetrate more consistently and resulting in more uniform exposure. Thinner, stabilised tissue also reduces scattering and random noise, increasing the clarity and contrast of the image (Fico et al. 2023).

These effects help ensure clear visualisation of all regions of the breast, leading to more reliable diagnosis. There is also a disadvantage to compression, namely discomfort and pain during mammography. The radiographer's role is to find a balance between achieving better image quality by minimising breast thickness and avoiding excessive pain and discomfort for patients (Branderhorst et al., 2015).

7. Patient comfort and experience during mammography

The results indicate that discomfort is influenced by several interrelated factors, including demographic characteristics, anatomical features of the breasts, previous surgical procedures, and psychological factors. Radiographers reported that younger patients and those with dense breasts more frequently experience moderate to severe discomfort. Increased sensitivity was also observed in patients with a history of biopsies or lumpectomies. Among ethnic groups, Asian women were perceived as more sensitive, which technologists believe is primarily due to the higher density of their breasts. The most important physical factors contributing to discomfort were the force and duration of compression, which together accounted for most of the intense discomfort experienced during the examination. Mechanical factors, such as pressure on the chest wall and the hard edges of the mammography platform, also played a significant role. An important focus of the research is the psychological aspect of mammography. Appropriate and clear communication from radiographers about the course of the examination was found to be the most influential factor in reducing perceived discomfort (Mendat et al., 2017).

Mammography is associated with discomfort, pain, and fear for many patients, primarily due to the mechanical compression of the breasts, which is necessary to obtain diagnostically high-quality images. Pain and unpleasant experiences are among the most frequently cited reasons for avoiding or postponing screening mammography, which can negatively affect early detection of breast cancer. In addition to the physical discomfort itself, the psychological aspect also plays an important role, as fear of pain and insufficient explanation of the procedure increase tension and negative expectations before the examination. Fujifilm has developed the Comfort Comp function with the aim of improving patient comfort during mammography. The system works by automatically reducing the compression force after the initial breast compression, thereby shortening the time during which the breast is exposed to maximum pressure. As a result, the sensation of pressure is less intense and shorter in duration, which patients perceive as less painful and more tolerable. Survey results showed a positive impact of Comfort Comp on patients' subjective experience of mammography. More than half of the participating patients had a negative overall perception of mammography before the examination. After the explanation of how Comfort Comp works and after the examination itself, most patients reported feeling more relaxed and experiencing less perceived discomfort or pain. Nearly four fifths of the patients stated that the feature made them feel better during the examination, and the vast majority expressed a desire for the function to be used in their future mammography appointments (Fujifilm, 2023).

Smith (2017) emphasises that reducing pain is crucial not only for improving the patient experience but also for increasing participation in regular screening, as pain is one of the most common reasons women avoid mammography. To address this, Hologic has developed solutions to reduce discomfort, with particular focus on the SmartCurve™ system, which is specifically designed to enhance comfort. SmartCurve uses a curved compression paddle that better conforms to the natural shape of the breast, allowing a more even distribution of pressure. As a result, localised pain is reduced, and the curved edge along the chest wall decreases the likelihood of pinching. Additionally, faster tomosynthesis scans shorten the time a patient must remain under compression, further improving comfort. A clinical study involving 68 women demonstrated a significant improvement in comfort among those who previously reported moderate to severe pain. Among women who rated their pain as 5 or higher with the standard paddle, 93% reported reduced pain when using the SmartCurve system. Improvements were observed in both CC and MLO projections. Smith (2017) also mentions MammoPad®, a soft foam cushion that further enhances comfort by reducing the sensation of a cold surface and softening the pressure from the device's harder components.

Men with breast cancer often find mammography to be a psychologically challenging procedure. For many, it is associated with feelings of shame, stigma, and a threat to their sense of masculinity. As breast cancer is socially perceived as a women's disease, men undergoing diagnostic procedures involving the breast frequently feel less masculine and uncomfortable. Mammography is conducted in environments designed almost exclusively for women, which often makes men in waiting rooms and examination areas feel they do not belong, reinforcing feelings of not fitting in and isolation (Abboah-Offei et al., 2024). The absence of mammographic screening for men, low general awareness, and the shame that often arises at diagnosis can lead to avoidance of treatment, delayed help-seeking, and poorer prognosis in men (Constantinou et al., 2023).

8. Discussion

Breast compression in mammography remains one of the most challenging aspects of the imaging process. The literature consistently highlights its dual role in improving image quality and reducing radiation dose to the breast. However, it is also the main source of patient discomfort in mammography. Technically, breast compression enhances spatial resolution, minimises tissue overlap, and stabilises the breast, which together improve image quality and diagnostic accuracy. The absence of standardised compression protocols results in variability in the applied compression force, often influenced by the technologist's experience and patient tolerance. Studies indicate that excessive compression does not proportionally improve image quality but significantly increases pain, which can reduce participation in screening programmes. Psychological factors, such as fear and inadequate communication, further increase discomfort, highlighting the importance of patient-centred approaches. Innovations such as Comfort Comp, SmartCurve, and MammoPad® demonstrate that technological solutions can reduce discomfort without compromising image quality, however, these solutions are not yet universally available in clinical settings.

9. Conclusions

Breast cancer remains one of the most common malignancies among women worldwide, with mammography as the standard imaging modality for early detection and population-based screening. Breast compression is an essential part of the mammographic examination, as it reduces breast thickness, improves image quality, and enables radiation dose optimisation. However, excessive compression can cause pain and discomfort, potentially discouraging patients from participating in regular screening programmes.

The findings of this review highlight the need for a balanced approach to breast compression, combining technical image optimisation with patient-centred care. The implementation of clearer compression guidelines, increased availability of comfort-enhancing technologies, and effective communication by radiographers are key factors in reducing patient discomfort without compromising diagnostic quality. Future research should focus on defining optimal compression parameters tailored to individual breast characteristics and further evaluating technological solutions aimed at improving patient experience. Achieving high-quality imaging while minimising discomfort is essential for improving screening adherence and ultimately facilitating early detection of breast cancer.

Conflicts of Interest: The authors declare no conflict of interest.

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