



Design and Development of Wound Dressing by Using Commercial Antiseptic Liquid

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Abstract Modern wound dressings are expensive for the majority of the people of 3rd world countries. There is a possibility to design and develop a proper and low-cost dressing that will have the properties of modern wound dressing. The aim of this research work is to develop a low-cost wound dressing with the properties of an antibacterial, absorbent, non-adherent, and capable to maintain a moist environment around the wound. The commercial antiseptics Dettol and Savlon were applied with different concentrations and M: L ratios on the cotton gauze fabric by pad dry method and the ZOI (zone of inhibition) was evaluated against *E. coli*. The antibacterial behavior exhibits even after one year. An absorbent layer of cotton fabrics, cotton fiber, and viscous fiber are used to assess their ability to absorb liquid. The absorbency and retention value of the absorbing layers were evaluated in g/g and g/cm². In a non-adherent layer, the gauze fabric was dip-coated using PVA (poly (vinyl alcohol)) polymer solution using a padding mangle. The peel-off force of PVA-coated fabrics was measured using a gelatin wound exudates model and UTM (universal testing machine). The obtained antibacterial and absorbency results were compared with commercial wound dressing and have shown promising results. The PVA-coated fabric was non-adherent to the wound and maintain a moist environment on the wound surface. So, the developed PVA-coated antibacterial wound dressing with cotton fiber absorbent layer can be used as an alternative to branded wound dressing for the poor people of third world countries.

Keywords Antiseptic liquid · Antibacterial · Non-adherent · Wound dressing

Introduction

Disruption of continuous skin is called as wound. It is from simple cut in the epithelial to deeper like tendons, muscles, vessels, organs and may be bone [1, 2]. Whether simple or deep wounds, there is a need to protect the wound from the environment. The wound dressings are used to protect the wound and help for healing. In 2500 BC the clay tablets were used for wound treatment. In 1600 BC, oil or grease-soaked, plastic-covered linen strips were used as a wound dressing. In 460–370 BC, water, milk, honey, oil, vinegar, and resin were used for wound healing treatment. In the nineteenth century, antibiotics came into the market and it was a big breakthrough in the treatment of wounds. In the twentieth century, modern dressings like film, hydrogel, foam, hydro fiber, alginate, and collagen dressings were introduced in the market, and followed by the late twentieth century the moisture wet dressings were introduced [3–6]. The 10 cm × 10 cm size modern wound dressings are having a price range from 20 to 100 Indian rupees in the markets. Due to the high cost of the product, the peoples are not ready to buy the dressing and literally, it may not be affordable for many Indians, particularly in rural India. Due to improper wound dressing, infections happen. Infection is the main reason for the delay in wound healing. External wound, burn, and chronic wound have mostly been affected by infection and also involve 75% of death in burn wound [7]. Open wounds are mainly contaminated with bacteria. The growth of bacterial biofilm, multi-resistance organisms, and high bacteria levels are the reason for delaying wound healing. Infection results in local hypoxia, tissue death, vessel occlusion, and an increase in

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wound size [8, 9]. Medicare beneficiaries 2018 data said that 8.2 billion people have wounds with or without infection. The majority of people are infected by surgical wounds and chronic wounds. Total medicare expenses range for all types of wounds from 28.1 billion to 96.8 billion in American dollars [10]. The exudates rate of leg ulcer, granulating wound, skin done sites, partial thickness burn and full thickness wounds were 0.60, 0.51, 0.42, 0.43, and 0.34 g/cm², respectively [11]. There is a need to absorb the excess exudates from the wound. Excess exudates are the main sources of bacteria growth and which are responsible for increasing the healing time. Wound dressing should capable of absorbing the excess exudates. The full absorption of exudates also delays wound healing and needs a moist environment in the wound bed to fast healing. So, there is a need for moisture wet dressing for wounds [12]. In the case of the granulation stage, tissue growth is higher in the wound area. At this time a non-adherent dressing surface is needed for the wound. Otherwise, the newly growing tissue grows over the dressing material and makes it difficult to remove the dressing material due to the damage to the tissue. Moreover, the damaged tissue increases the healing time [13]. There is no such wound dressing material available which is low cost and has the properties of absorbency, antibacterial, non-adherent and also there is no such study regarding the use of commercial antiseptic liquid as an antibacterial agent for developing wound dressing material. So, there is a need for wound dressing having the properties of absorbency, antibacterial, non-adherent and maintaining a moist environment on the wound at a low cost. In this research work, the composite dressings were prepared with antibacterial, absorbent, and non-adherent layers. In the antibacterial layer, the leading commercial antiseptics were applied to the cotton gauze fabric. In the absorbent layer, three varieties of bleached fold cotton gauze fabrics, and three different areal density (g/m²) bleached cotton and viscose fibrous matts were used. To develop the non-adherent property, the PVA was coated over the top layer of gauze fabric before antiseptic liquid treatment. It is observed that the developed multilayer wound dressing is working similarly to commercial wound dressings in terms of ZOI (zone of inhibition) and g/g of absorbency.

Table 1 Specification of the gauze textile fabrics used in wound dressing

Type of gauze fabric	Ends per cm and Picks per cm	Warp and weft yarn linear density (Tex)	Areal density of the fabric (g/m ²)
Gauze fabric A	16×9	25.6×25.6	64.1
Gauze fabric B	8×5.5	28×21	32.2
Gauze fabric C	9×7	13×13.7	20.8

Materials and Methods

Materials

Dettol (100% pure) and Savlon (100% pure) antiseptic liquids were purchased from Dispensary, NIT Jalandhar, India. Commercial gauze fabric (purchased from Royal Surgicals, Tamilnadu), cotton fibers (Purchased from Meena Surgicals), and Viscose fiber (KT Spinning mill Pvt. Ltd, Tamilnadu). PVA (purchased from SDFCL, the molecular weight of 140,000). The specification of the textile materials is given in Tables 1 and 2.

Methods of Manufacturing of Wound Dressing

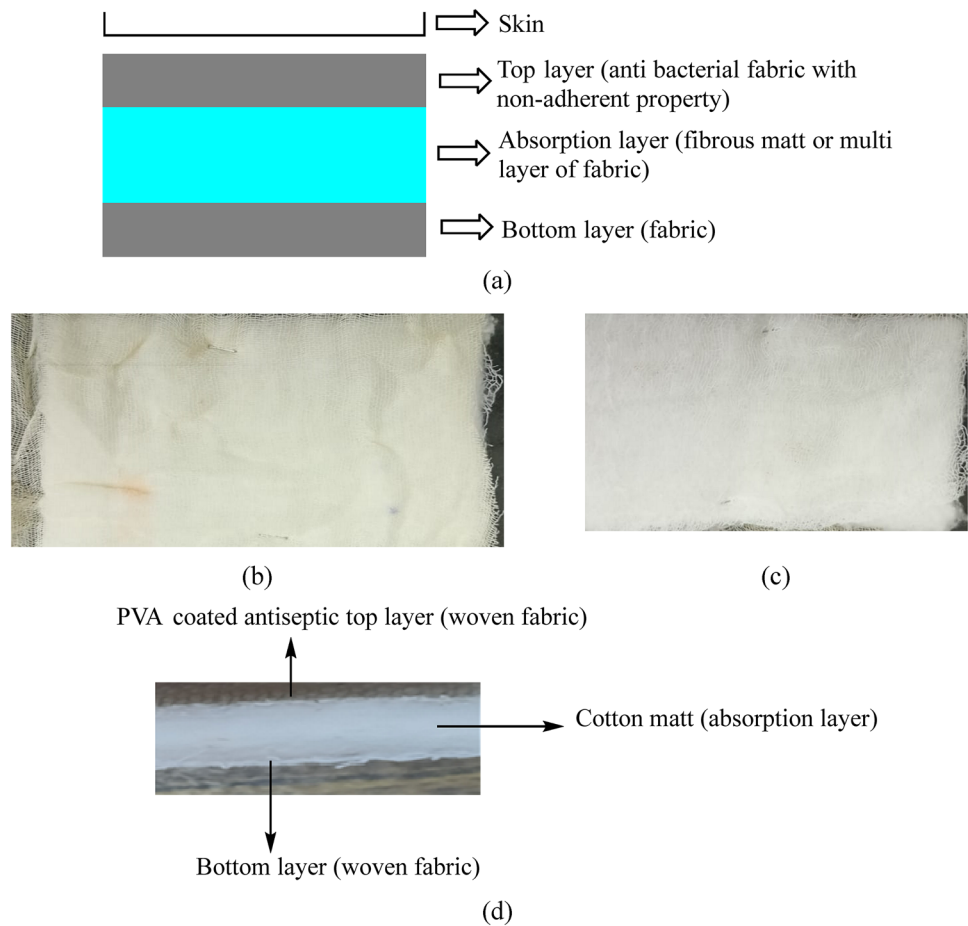
Wound Dressing Material

Figure 1, indicates the different layers of the wound dressing. It consists of top layer of fabric with antibacterial property as well as non-adherent property and a bottom layer and an absorption layer in between them. In order to prepare the absorbent layer, two different classes of absorbent layers were prepared. Class I was prepared by using three varieties of fabric (areal density of 64, 32, and 21 g/m²) with folded as 8, 12, and 16. Class II was prepared in the form of fibers matt by using bleached cotton and viscose fiber. The fiber matt was prepared by using a miniature carding machine with three different areal density (g/m²), cotton (129, 178, and 245 g/m²) and viscose (130, 232, and 359 g/m²) fibrous matts were prepared. The schematic diagram and original photographs of wound dressing are given in Fig. 1a, b, c, d, respectively.

Table 2 Specification of the textile fibers and fiber matt used in wound dressing

Types of fibers	Average fiber length (mm)	Fineness	Areal density of the fiber matt (g/m ²)
Cotton	24	3.5 mic	129, 178, and 245
Viscose	38	1.2 d	130, 232 and 359

Fig. 1 (a) Schematic diagram of wound dressing (b) Top layer, (c) Bottom layer and (d) cross section of developed wound dressing



Manufacturing of Antiseptic Layer by Application of Antiseptic Liquid on Fabric

For the manufacturing of antiseptic layers, the gauze fabric (areal density of 64 g/m²) was dipped into the prepared antiseptic solution for adsorption of the antiseptic liquid. The dipped fabrics were taken from the solution for the padding process. During the padding process, the speed and pressure were kept at 7.2 m/min and 1 kg/cm², respectively. Then the fabrics were subjected to drying at 60 °C. After that, the antiseptic fabric was stored at room temperature for further use.

Development of Non-adherent Property by the Coating of PVA on Fabric

In order to develop the non-adherent property, the top layer gauze fabric was coated with PVA (areal density of 64 g/m²) with different concentrations (2%, 4%, 6%, and 10%) (before antiseptic liquid treatment). The different concentration PVA solutions were prepared by stirring with magnetic stirrer for two and half hours. Once the solution was ready, it was applied on fabric to be used as top surface by using a

padding mangle. In padding mangle, the speed and pressure were maintained at 7.2 m/min and 1 kg/cm², respectively. Then the padded fabric was allowed to dry for 24 h at room temperature. After drying the sample was heat set in an oven at 180 °C for 6 h. Then the heat set samples were stored at room temperature for 24 h.

The top layer fabric is only coated with PVA and antibacterial solution. There after the coated top layer fabric was stitched with bottom layer (normal fabric) with absorbent core in between them.

Characterization of Material

Antibacterial Efficiency

The AATCC- 147 test procedure was followed to evaluate the antibacterial efficiency of the antiseptic fabric. The inoculum was prepared by using bacteria. E. coli was procured from the Bio-Technology department, NIT Jalandhar. Agar media and petri dish were autoclaved for 20 min at 115 °C temperature and 15 psi pressure. After that, the agar media was poured into the Petri plates for gel formation. Followed by, the 100 µl of bacteria was spread by using an L rod in

agar media. After that, the 23 mm diameter UV sterilized antiseptic textile sample was placed at the center of the Petri plate. Then the plates were placed in inhibitor for 24 h at 37 °C. The zone of inhibition was evaluated by using the method mentioned in Fig. 2.

$$\text{Zone of inhibition (ZOI)} = (D - d)/2(\text{mm})$$

where, d-fabric diameter (mm), D-the inhibition zone diameter (mm).

Absorbency Test

Here, BS EN 13,726–1: 2002 standard was followed to determine the absorbency of the absorbent layer. The saline solution was prepared by adding 2.298 g of sodium chloride and 0.368 g of calcium chloride into 1 L of de-ionized water and maintains 37 °C temperature. The 5 cm × 5 cm sample specimens were initially weighed and then placed into the Petri plate with the prepared solution. Then the Petri plates were kept in inhibitor at 37 °C temperature. After 30 min, the sample was taken out with gentle holding in the corner for 30 s to drop off some saline water; then, the sample should be weighted. And the absorbency was calculated by the given formula.

$$\text{Absorbency (g/g)} = \frac{W_2 - W_1}{W_1} (\text{g/g})$$

$\text{Absorbency (g/cm}^2\text{)} = \frac{W_2 - W_1}{25} (\text{g/cm}^2)$ where, W_1 = Initial weight of the sample, W_2 = Weight of the sample after absorption of saline.

Retention Test

Here, BS EN 13,726–1: 2002 standard was used and the same procedure is followed by the absorbency test up to taking out of the sample. After that the wet sample was pressed by 5 kg of weight for 20 s then the samples were weighted. And the retention was calculated by the given formula.

$$\text{Retention (g/g)} = \frac{W_3 - W_1}{W_1} (\text{g/g})$$

$\text{Retention (g/cm}^2\text{)} = \frac{W_3 - W_1}{25} (\text{g/cm}^2)$ where, W_3 = Weight of the saline absorbed sample after applying weight.

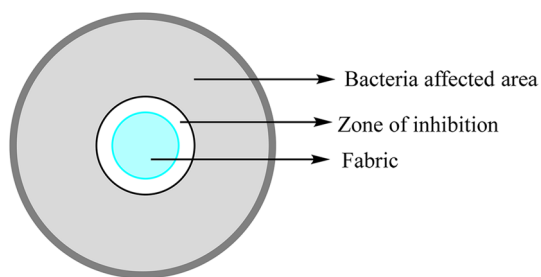


Fig. 2 Schematic view of antibacterial assessment

Peel-off Force Measurement

In order to evaluate the performance of the non-adherent layer, the gelatin wound exudates model was prepared with 40% of gelatin and 2% of glycerin at 70 °C, two drops of the prepared solution were applied over the forearm skin surface. Then the 2 cm × 15 cm textile specimen samples were prepared and 7 cm of length textile sample were placed over the gelatin applied forearm. After 5 min the samples were tested by UTM (Universal Testing Machine) to evaluate the force required to peel off the dressing from the forearm [14].

Fourier Transformation Infrared Spectroscopy Analysis (FTIR)

The FTIR analysis of pure Dettol, Savlon and Dettol and Savlon treated fabrics were carried out by using FTIR, BUKER, ALPHA II, Germany with wavelength of 600 to 4000 nm.

Results and Discussions

Antibacterial Behavior of Wound Dressing

The Dettol and Savlon are the two leading antiseptic liquids applied on textile fabric to study the antibacterial behavior of textiles to be used as a part of wound dressing. So, the antibacterial efficiency of the wound dressing was determined by using the agar–agar diffusion test by using *E.coli* and the zone of inhibition was measured [15].

Effect of Antiseptic Concentration

2%, 5%, 25%, 50%, and 100% concentrated Dettol and Savlon solutions were applied to the gauze fabric (areal density of 64 g/m²) then the antibacterial efficiency was evaluated. The result is given in Figs. 3 and 4. Figure 3 a, b, c indicate the zone of inhibition with different concentration of antiseptic liquid.

Zone of inhibition is evaluated in mm from the samples and plotted in Fig. 4. It is observed from Fig. 4 as the concentration of antiseptic liquid increases, zone of inhibition (ZOI) is also increased. So, with the increase in concentration antiseptic liquid increased the ZOI is increased up to 50% concentration value. There after there is a very little change in the size of inhibition zone [16]. It is noted from literature that the standard ZOI of wound dressing is in the range of 2 to 6 mm [17, 18]. From Fig. 4, it can be said that the 5% concentration of antiseptic liquid is good enough to give the standard ZOI. So, 5% antiseptic liquid absorbed on fabrics is sufficient to develop antiseptic wound dressing material [19].

Fig. 3 Zone of inhibition with different concentrations of antiseptics **a** 5% of Dettol, **b** 50% of Dettol, **c** 100% of Dettol

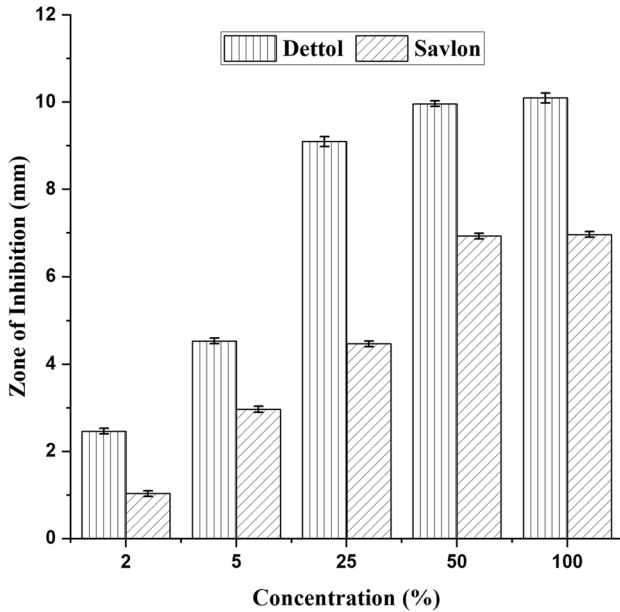
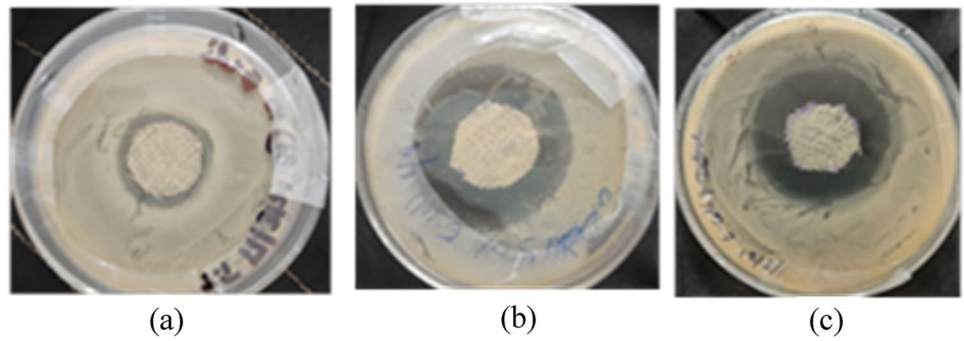


Fig. 4 Effect of antiseptic concentration on zone of inhibition (ZOI)

Effect of Material to Liquor Ratio on ZOI

The prepared 5% concentrated antiseptics solutions were used to treat the 64 g/m² areal density gauze fabric with 1:10, 1:20, and 1:30 material to liquor ratios and the size of the antibacterial zones were measured for each case. The result is given in Fig. 5.

From Fig. 5, it is observed that there is a little change in ZOI size with the change in material to liquor ratio. ZOI is slightly increased for Dettol and reduced for Savlon. However, statistically there change in the size of ZOI is insignificant in regards to material to liquor ratio ($p=0.72$). So, the value obtained at 1:10 liquor ratio of the ZOI for 64 g/m² areal density gauze fabric is good enough for the antibacterial activity as per the standard data. The minimum liquor ratio reduces the cost of production of the material [20, 21]. Among the three liquor ratios 1:10 was minimum. So, 1:10 liquor ratio is used for the preparation of the antibacterial layer of wound dressing.

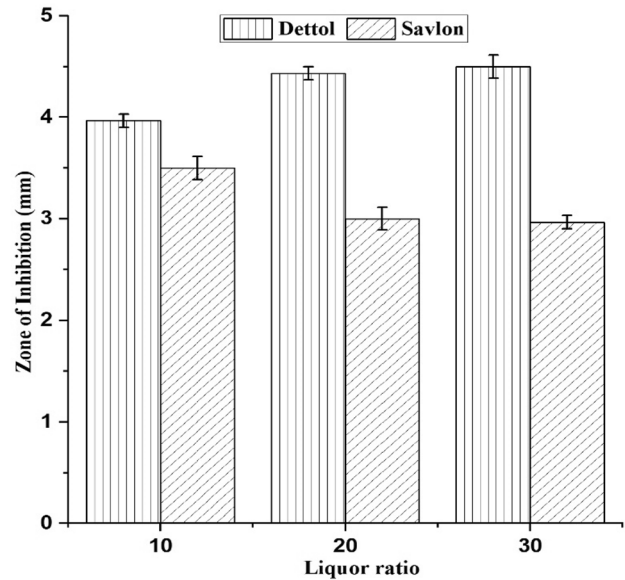


Fig. 5 Effect of material to liquor ratio on ZOI

Effect of Storage Time on Antibacterial Behavior of Treated Gauze Fabric to be used as Wound Dressing

The antibacterial behavior of antiseptic treated 64 g/m² areal density fabric was stored for a long period of time and the ZOI inhibition was measured to check the stability of the antibacterial effect of the treated fabrics with time. Here, the 100% concentration of antiseptic liquid solution and 1:10 material liquor ratio was used to treat the gauze fabric. The result is given in Figs. 6 and 7. Figure 6 a, b and c indicates the zone of inhibition of treated fabric after day one of application, after 5 months and tested after 1 year of storing of antiseptic fabric.

It is noted from Fig. 7 that there is hardly any change in the size of ZOI in regards to the antibacterial efficiency of the treated fabric, after day one to 12 months of the stored sample. The antiseptics were adsorbed in the fabrics and it remains there in the fabric even after 12 months. According to that, the Dettol and Savlon treated antibacterial fabrics may be stored for a longer time.

Fig. 6 ZOI of stored antiseptic fabric **a**-day one after application, **b**-5 months stored sample, and **c**-1-year stored sample

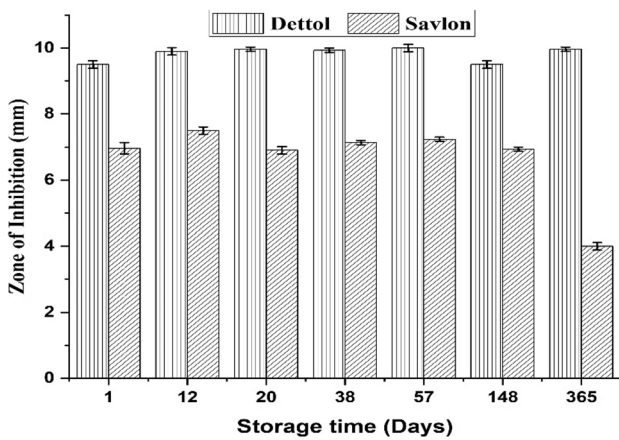
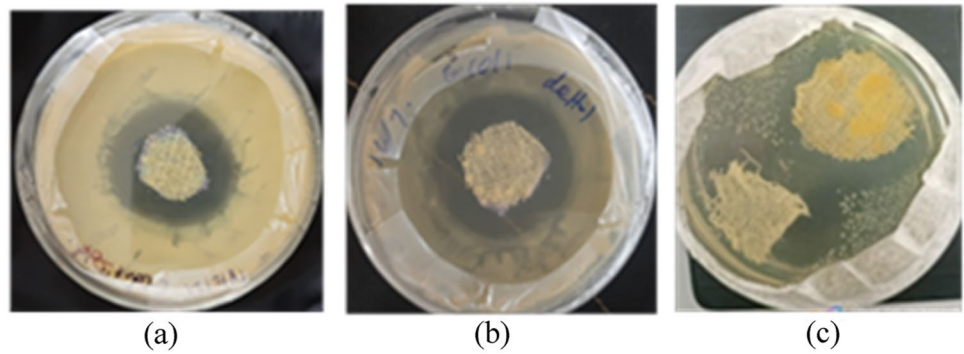


Fig. 7 Effect of storage time on Zone of Inhibition (ZOI)

Absorbency and Retention Behavior of Absorbent Layer

Other than the antiseptic behavior, another most important requirement of wound dressing material is absorbency and retention of wound exudates. Three different areal density (g/m^2) of bleached gauze fabrics, bleached cotton and viscose fibrous matt were used for the absorbent layer.

Effect of Areal Density (g/m^2) on Absorbency and Retention

Three different gauze fabrics with areal density values 64, 33, and 21 g/m^2 were folded as 8, 12, and 16 layers of thick materials. The absorbency and retention behavior of these folded fabrics were measured, and the results are given in Figs. 8 and 9, respectively.

It is observed from Fig. 8 that as an areal density (g/m^2) of the fabric is increased, the liquid absorbency value of the fabric is increased. Furthermore, with increase in number of layers of the given areal density (g/m^2) fabric the absorbency of the fabric is also increased. The fabric with 64 areal density (g/m^2) value with 16 layers shows the highest value absorbency of the liquid due to more amount of fibers as

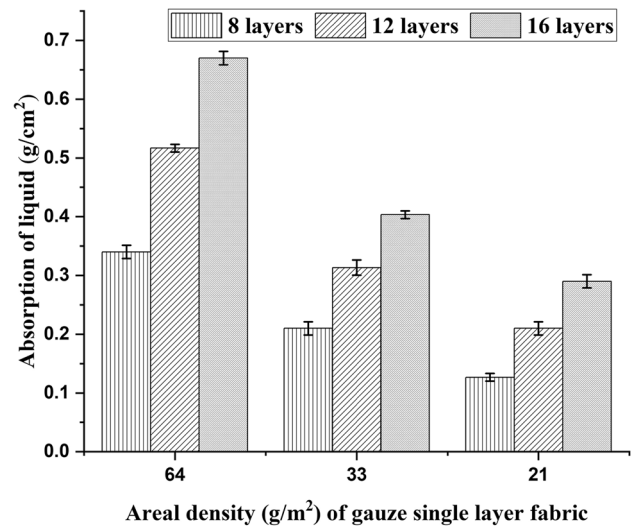


Fig. 8 Effect of multilayer fabrics on absorbency

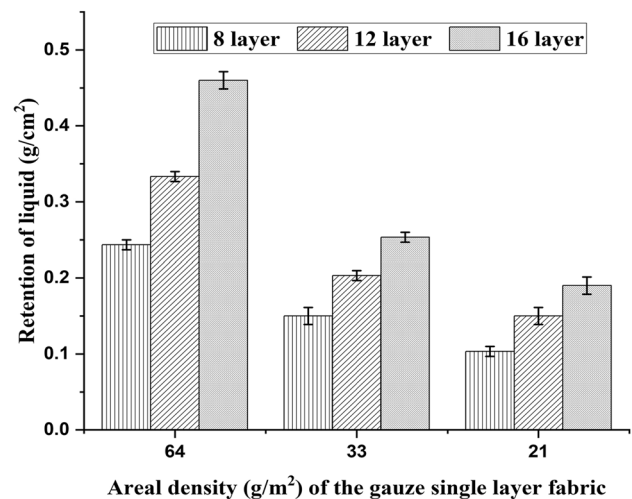


Fig. 9 Effect of multilayered fabric on retention value

compared to lower areal density (g/m^2) multilayered fabrics [22].

From Fig. 9, it can be seen that the retention behavior of multilayer fabrics follows the same trend as absorbency. But for all multilayer fabrics, the retention value of the fabrics was less than the absorbency value [23]. The absorbency value of the fabrics was about 1.5 times higher than the retention value. Regarding absorption and retention of liquid, it is also observed that at low areal density (g/m^2) multilayer fabrics the impact on absorption and retention of liquid are less as compared to high areal density (g/m^2) multilayer fabrics [24].

The absorbency and retention behavior of three different areal density of cotton (areal density of 129, 178, and 245 g/m^2) and viscose (areal density of 130, 232, and 359 g/m^2) fibrous matt were also measured. The results of cotton and viscose fibrous matt are given in Figs. 10 and 11, respectively. Here, increasing the areal density value of the matt increases the absorbency as well as the retention value. The trend is similar for viscose fibrous matt also.

Comparison of Liquid Absorption and Retention Behavior of Fabrics and Fibrous Matt

From Fig. 12, it is clear that lower areal density (g/m^2) gauze fabric absorbency and retention value in g/g are higher as compared to higher areal density (g/m^2) gauze fabrics. This may be due to the high porosity of low areal density (g/m^2) fabric. Higher porosity fabrics have large pore which is also responsible for can absorb more amount of liquid in terms of g/g due to higher space between yarns [25]. Similar kind of observation was noted in the literature, where high value of porosity and air permeability of the fabric absorbs the higher amount of liquid [26].

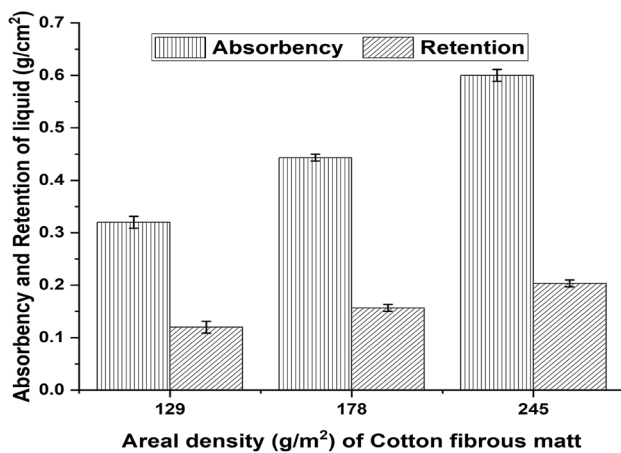


Fig. 10 Effect of cotton fibrous matt areal density (g/m^2) value on absorbency and retention

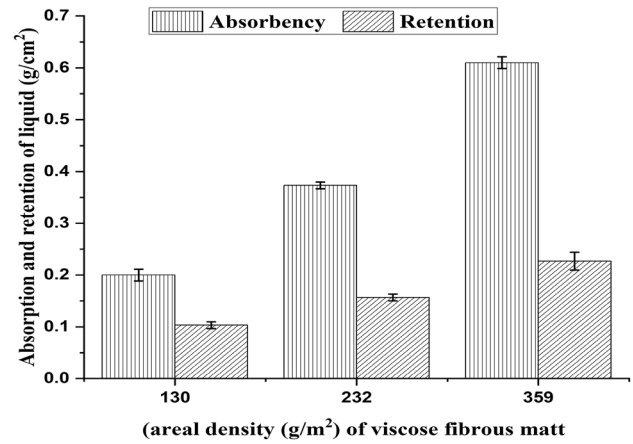


Fig. 11 Effect of areal density (g/m^2) on absorbency and retention of viscose fiber matt

In the case of viscose and cotton fibrous matt, the cotton matt has high absorbency and retention value may be because the cotton fibrous matt is made of medicated cotton fiber which contains immature and short length of the cotton fiber. With the decrease in the length of the fiber, there is an increase in the absorbency due to more available surface area. The cotton fiber length was almost half the length of viscose fiber. Immature fibers also absorb more water due to available of higher portion of primary wall in the fiber. Similar kind of effect is observed by Rousselle et al. where they have experimented with different immature fiber [27]. Moreover, cotton fiber matt has high porosity (about 94%) than viscose fiber matt (about 91%) [28]. That may be reason for higher absorption of liquid by cotton fiber matt as compared to viscose fiber matt.

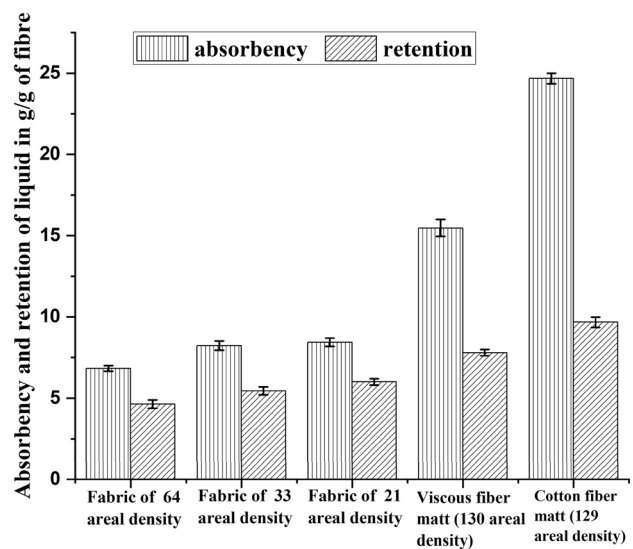


Fig. 12 Comparison of fabrics and fiber matt in terms of g/g of fibre

As compared to cotton gauze fabrics, the cotton fiber matt is having excellent absorbency and retention value in terms of g/g of the fabric [29]. The cotton fiber matt was almost having 3 times higher absorbency and 2 times more retention value than the gauze fabric which are commonly used in wound dressing. So, cotton fibrous matt may be used as an absorbent layer in wound dressing material as it has got the highest absorption and retention values in terms of g/g and also will be cheaper than gauze fabric.

Effect of PVA Concentration on Wound Dressing Surface on Peel-off Force

The top layer of the wound dressing fabric was coated with PVA of concentration 2%, 4%, 6%, and 10%. Peel-off force was measured for coated fabrics by gelatin wound exudates model at the rate of 500 mm/min and 1000 mm/min rate by using UTM. The results of peel-off force are given in Fig. 13.

From Fig. 13, it is observed that as the concentration of PVA increases, there is a decrease in the peel-off force up to 4% concentration. After 4% concentration, there is no significant change in peel-off force. Hence, 4% PVA coating is used for the development of wound dressing. This coating will be useful for reducing the pain, during the removal of dressing from the wound site. PVA is a hydrophilic polymer and it will swell during the absorption of exudates [30, 31]. Because of swelling, the PVA can maintain the moist environment around the wound surface. The moist environment is useful for fast healing [32, 33]. So, by coating PVA on the top layer fabric, the non-adherent and moist environment properties can be introduced into the wound dressing material.

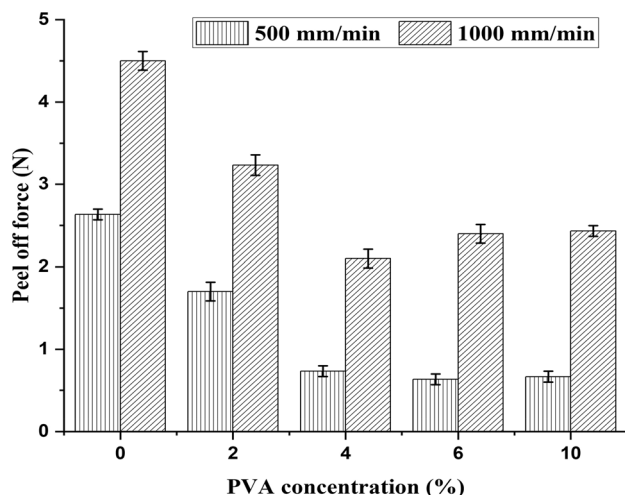


Fig. 13 Peel-off force measurement

Fourier Transformation Infrared Spectroscopy Analysis (FTIR)

FTIR of pure Dettol, Savlon, and cotton, cotton treated with Dettol and Savlon were performed to identify the kind of bonding between cotton and liquid antiseptic after adsorption. The IR spectra of Dettol, Savlon, raw cotton, Dettol and Savlon treated cotton fabrics are given in Fig. 14 a, b. It is observed from Fig. 14 a that peaks are appeared in the range of 3000 to 3400 cm^{-1} and in the range of 1400 to 1500 cm^{-1} due to presence of hydroxyl and amine group. In case of raw cotton, the peaks at 3259 and 1037 are visible due to presence of hydroxyl and CO– groups. The peaks are also visible in the range of 3600 to 3700 cm^{-1} and 1400 to 1600 cm^{-1} for antiseptic liquid treated fabric which were not present in pure Dettol, Savlon, and raw cotton fabric. So, this may be due to the presence of intermolecular hydrogen bond [34, 35].

Comparison of the Developed Wound Dressing Material with Commercial Wound Dressing Material

Comparison of Antibacterial Property

The result of antibacterial efficiency of commercial wound dressings available in the market was collected from international journals [17, 18]. These results were compiled and compared with the 5% concentration of Dettol and Savlon treated wound dressing fabrics developed in this work in terms of ZOI size. The total compiled results are given in Fig. 15.

It is noted from Fig. 15 that the Dettol and Savlon treated fabrics have more or less equal ZOI value when it is compared with different international commercial wound dressings material. In order to inspect whether the difference in ZOI values among developed wound dressing and commercial wound dressing is significant or not, a t-test was performed and observed statistically insignificant ($p=0.56$).

Comparison of Absorbency Property

The absorbency values of various types of commercial wound dressing materials were collected from the international journal [36]. These results were compiled and compared with the developed wound dressing with cotton fiber matt is used as an absorption layer and is given in Fig. 16.

It is observed that the cotton fibrous matt has got the higher value of absorbency than the alginates, foams and hydrocolloids but the absorbency values is lower than the collagen based wound dressing. The exudate amount to be absorbed in case of leg ulcer, granulating wound, skin done sites, partial thickness burn, and full thickness wounds were about 0.60, 0.51, 0.42, 0.43, and 0.34 g/cm^2 , respectively [11]. Here,

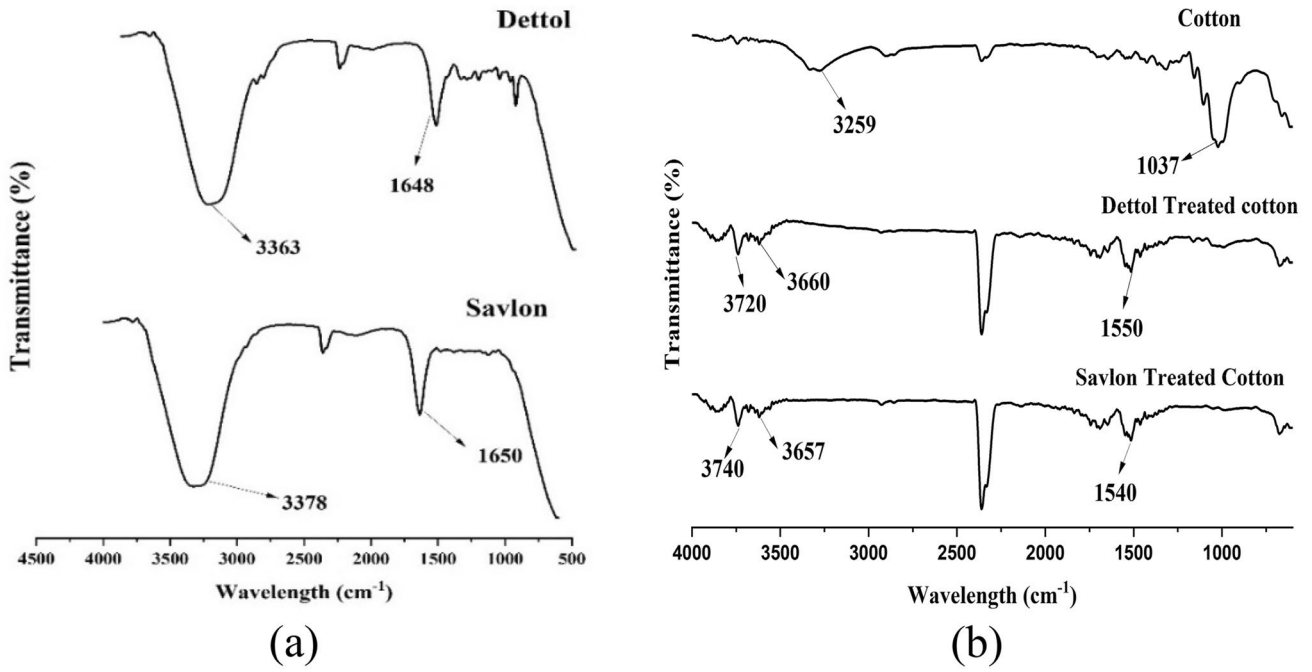


Fig. 14 FTIR spectra of (a) Pure Dettol and Savlon, (b) Raw cotton fabric, Dettol treated cotton fabric and Savlon treated cotton fabric

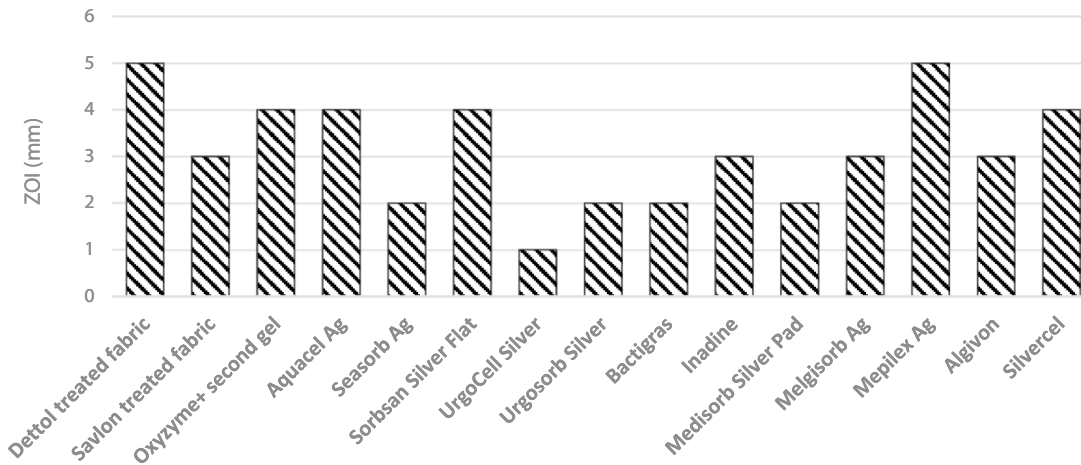
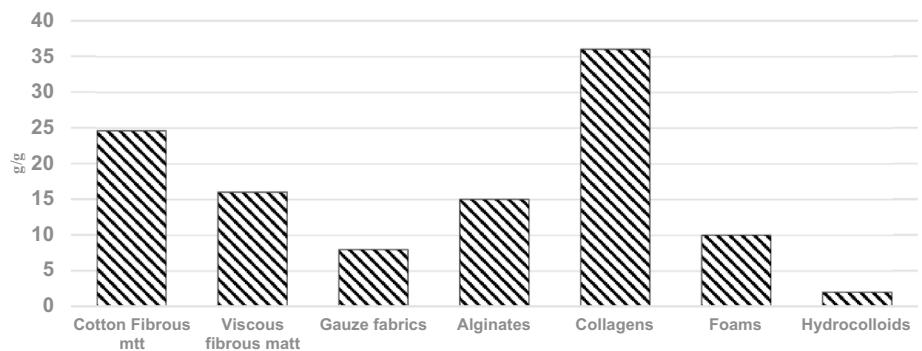


Fig. 15 Comparison of commercial antibacterial wound dressing

Fig. 16 Comparison of absor-bency behavior of commercial wound dressing



245 g/m² areal density cotton fibrous matt can absorb up to 0.60 g/cm². From this, it can be said that the cotton fibrous matt may be useful for all types of wounds in terms of its absorbency capability. However, to examine whether the difference in absorbency values of developed wound dressing and commercial wound dressing are significant or not, a t-test was performed and observed statistically insignificant ($p=0.45$). So, the developed wound dressing and commercial product may work with the same effectiveness.

Conclusion

In this work, a wound dressing was developed by considering antibacterial, absorbency, and retention and peel-off force properties. The 5% concentration with 1:10 material liquor ratio of antiseptics applied on the fabric have the zone of inhibition range of 3–5 mm similar to that of the international wound dressing. In the absorbent layer, the multilayer fabrics, viscose, and cotton fibrous matt having absorbency and retention values of 8.3, 15.2, and 24.6 g/g and 5.9, 7.7, and 9.5 g/g, respectively, while the modern wound dressings like hydrocolloids, foam, alginate, and collagen have absorption values 2, 10, 15, and 36 g/g, respectively. The peel-off force of 4% PVA-coated fabric was 4 times lesser than the normal gauze. Moreover, PVA was swelling after absorbing the exudates and maintain the wet moist environment on the wound surface. It can be a simple multilayer dressing produced by using gauze fabric treated with commercial antiseptic liquid with PVA coating and cotton fibrous absorbent layer that is good enough for giving a similar result to that of modern wound dressing.

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Declarations

Competing interests The authors declare that no competing interests exist.

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