



A review of three dimensional knitted spacer fabrics for medicine and healthcare and recent developments

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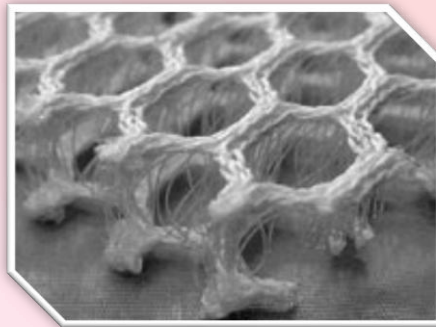
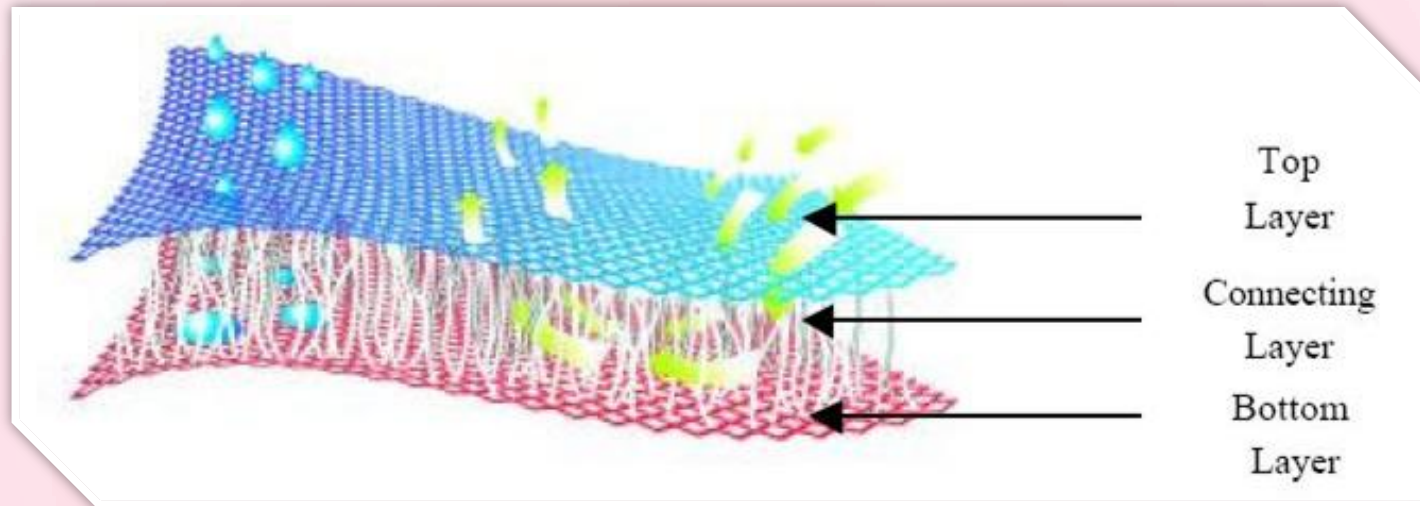
Content

1. Research Background
2. Research Objective
3. Research Methodology
4. Results and Discussion
5. Conclusion

1. Research **Background**

1. Research Background



3-Dimensional Knitted Spacer Fabrics



1. Research Background

- Good air permeability
- Good breathability
- Good thermal regulation
- Good moisture wicking properties
- Good compressional behavior

1. Research Background

| | | |
|------------------|---|--|
| | 3D warp knitted spacer fabrics | 3D weft knitted spacer fabrics |
| Knitting machine | Double needle bar Raschel machine | Double jersey circular knitting machine |
| |  |  |

Source from:

(Left) Armakan, D. M. and Roye, A. (2009). A study on the compression behavior of spacer fabrics designed for concrete applications. *Fiber and Polymers*, 10(1), 116-123.

(Right) EC21 Inc. (2013). Changzhou Wujin Yongguang Machinery Co., Ltd.

http://yongguang123.en.ec21.com/Ge2291B_High_Speed_Double_Needle--4783042_4783043.html

2. Research **Objective**

2. Research Objective

- Review the recent **developments** and **advancements** in **3D knitted spacer fabrics** used for **medicine and healthcare**

3. Research **Methodology**

3. Research Methodology

| | |
|-------------------|---|
| Search engines: | Google Scholar Scopus |
| Search Strings: | “3D knitted spacer fabrics” AND “medical” or “healthcare” or “hygiene” |
| Publication date: | 1 st January, 2005–10 th December, 2015 |
| Language: | English |
| Focus: | 3D warp and weft knitted spacer fabrics for medical and healthcare |

4. Results and Discussion

4. Results and Discussion

| Key words: | Total no. of articles available |
|---|---------------------------------|
| “3D knitted spacer fabrics” and “medical” | 344 |
| “3D knitted spacer fabrics” and “healthcare” | 109 |
| “3D knitted spacer fabrics” and “hygiene” | 90 |
| Related articles | 19 |

Bandages

Application

3D knitted spacer fabrics

- Provide a more optimum microclimate
- Distribute the pressure more evenly
- Offer excellent cushioning



Commercial two-layer bandage with padding bandage



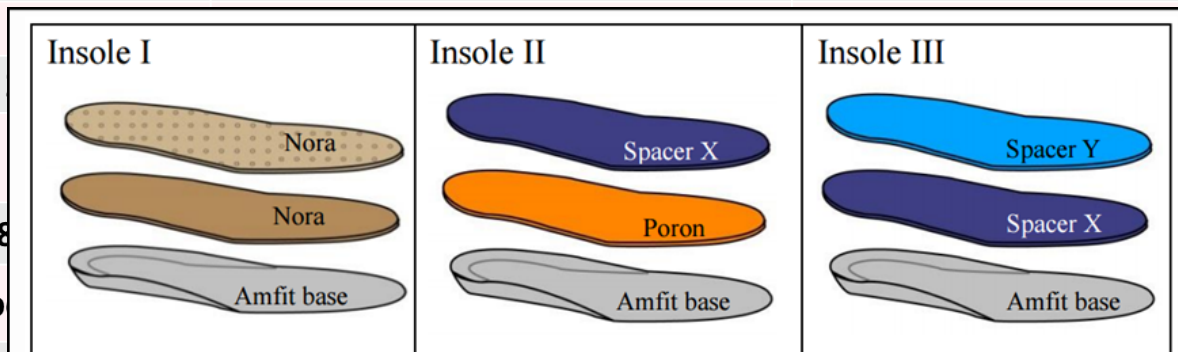
New 3D spacer bandage

Source from: Lee, G.A., Rajendran, S. and Anand, S., 2009. New single-layer compression bandage system for chronic venous leg ulcers. *British Journal of Nursing*, 18(Sup5), pp.S4-S18.

Orthotic insoles/ shoes Discussion

3D knitted spacer fabrics

- Provide comparable compression property as traditional materials
- Are washable, reusable and even biodegradable
- Have good breathability



Insoles made of different combinations of materials

Source from: Lo, W.T., 2014. *Development of plantar pressure relieving orthotic insoles for people with diabetes* (Doctoral dissertation, The Hong Kong Polytechnic University).

Tong et al., 2015

3D warp knitted spacer fabrics

Absorbent layer of wound dressings

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Bartels,

Trümper et al., 2011

Davies and Williams,

Lee, Rajendran and

Anand, 2009

Ye, Hu and Feng, 2008

Möhring and Schwab

Milosavljević and Šku

Pereira et al., 2006

Helde et al., 2005

Helde, Schwabe and

2005

Application

products

us leg ulcers

thermia prevention

ages

Orthoses

Discussion

3D knitted spacer fabrics

- Are moldable
- Have better heat and moisture exchange performance and breathability
- Prevent the maceration of skin while providing compression and warmth

Application

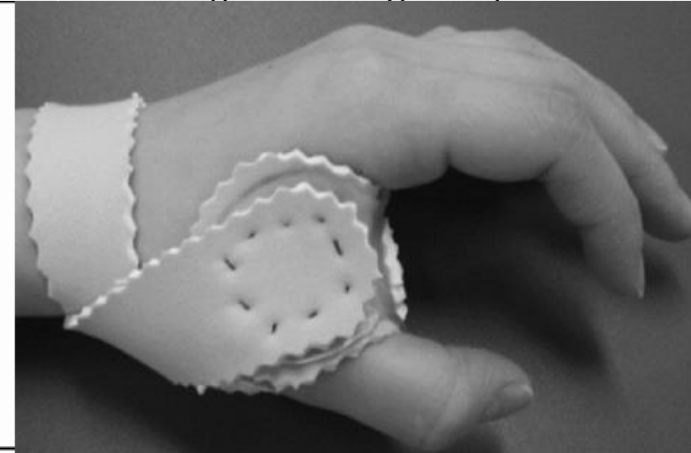
Tong et al., 2015

3D warp knitted spacer fabrics

Absorbent layer of wound dressings

Yu et al., 2015

Pressure gloves for hypertrophic scars



A simple web spacer for thumb opposition weakness

Source from: Tanaka, K., Saura, R., Houraiya, K. and Tanimura, H. 2009 'A simple and useful hand orthosis for patients with amyotrophic lateral sclerosis: a simple web spacer for thumb opposition weakness', *Disability and Rehabilitation: Assistive Technology*, 4(5), pp.364-366.

Helde et al., 2005

3D warp knitted spacer fabrics

Orthopedic shoe

Helde, Schwabe and Möhring, 2005

3D knitted spacer fabrics

Elastic short traction bandages

Pressure therapy gloves

Discussion

| | | Application |
|-------------------|--------------------------------|--|
| Tong et al., 2015 | 3D warp knitted spacer fabrics | Absorbent layer of wound dressings |
| Yu et al., 2015 | 3D weft knitted spacer fabrics | Pressure gloves for hypertrophic scars |
| Abou-Taleb, 2014 | 3D weft knitted spacer fabrics | Knee braces |
| Brisa, Helb | | al for hip |
| Fournier e | | e therapy |
| Yick et al., | | |
| Ghorbani e | | |
| Luximon, 2 | | |
| Viju et al., | | |
| Bartels, 20 | | |
| Trümper e | | |
| David | | |
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| Held | | |
| 2005 | | |



Original modality



Spacer fabric insert for pressure

Source from: Yu, A., Yick, K. L., Ng, S. P. and Yip, J. (2015) 'Orthopaedic textile inserts for pressure treatment of hypertrophic scars', *Textile Research Journal*, 0040517515573409.

3D knitted spacer fabrics

- Have better air permeability, moisture absorbency and wicking properties
- Are more comfortable and breathable
- Provide comparable interfacial pressure

3D knitted spacer fabrics

Elastic short traction bandages

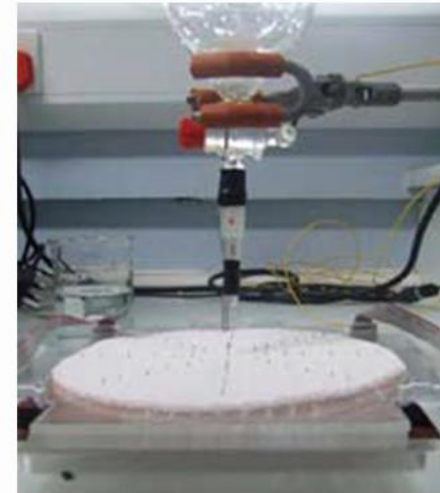
Absorbent medical textiles

Discussion

| | | Application |
|-----------------------|--------------------------------|--|
| Tong et al., 2015 | 3D warp knitted spacer fabrics | Absorbent layer of wound dressings |
| Yu et al., 2017 | 3D knitted spacer fabrics | Pressure gloves for hypertrophic scars |
| Abdullah et al., 2015 | 3D knitted spacer fabrics | Knee braces |

3D knitted spacer fabrics

- Provide good absorption of exudates and cushioning effect
- Offer good air permeability and water vapor permeability
- Have comparable thermal conductivity



Test for the fabric absorbency

Source from: Davies, A. and Williams, J. (2009) 'The use of spacer fabrics for absorbent medical applications', *Journal of Fiber Bioengineering and Information*, 1(4), pp. 321-329.

| | | |
|----------------------------------|--------------------------------|---------------------------------|
| Per Helde et al., 2005 | 3D warp knitted spacer fabrics | Knee braces |
| Helde, Schwabe and Möhring, 2005 | 3D knitted spacer fabrics | Orthopedic shoe |
| | 3D knitted spacer fabrics | Elastic short traction bandages |

Surgical products for hypothermia prevention

on

| | | Application |
|-------------------------------|---|---|
| Tong et al., 2015 | 3D warp knitted spacer fabrics | Absorbent layer of wound dressings |
| Yu et al., 2015 | 3D weft knitted spacer fabrics | Pressure gloves for hypertrophic scars |
| Abou-Taleb, 2014 | 3D weft knitted spacer fabrics | Knee braces |
| Brisa, Helbig and Kroll, 2015 | 3D warp knitted spacer fabrics | Mattresses |
| Fournier et al., 2014 | 3D warp knitted spacer fabrics with elastic nitinol wires | Orthopedic implant coating material for hip and knee replacements |

Thermal conductors incorporate into the pile zone of 3D warp knitted spacer fabrics

- Are used for hypothermia prevention
- Are lightweight and flexible

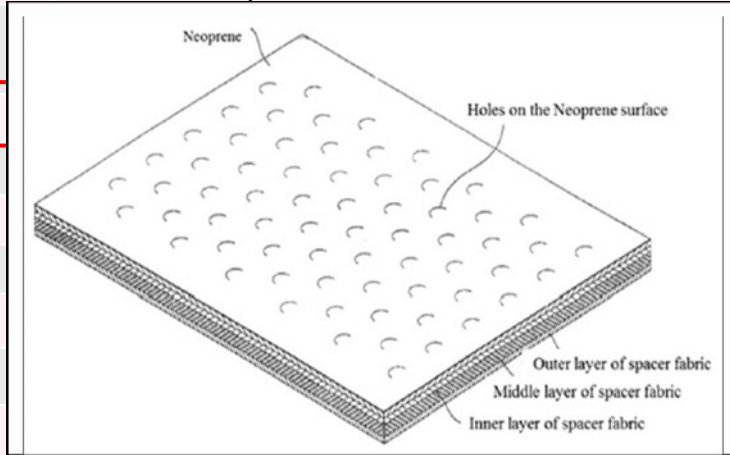
| | | |
|----------------------------------|--------------------------------|--|
| Ye, Hu and Feng, 2008 | 3D warp knitted spacer fabrics | Padding materials |
| Möhring and Schwabe, 2008 | 3D warp knitted spacer fabrics | Surgical products for hypothermia prevention |
| Milosavljević and Škundrić, 2007 | 3D knitted spacer fabrics | Compression bandages |
| Pereira et al., 2006 | 3D knitted spacer fabrics | Knee braces |
| Helde et al., 2005 | 3D warp knitted spacer fabrics | Orthopedic shoe |
| Helde, Schwabe and Möhring, 2005 | 3D knitted spacer fabrics | Elastic short traction bandages |

Joint damage prevention

| | | Application |
|-------------------------------|---|---|
| Tong et al., 2015 | 3D warp knitted spacer fabrics | Absorbent layer of wound dressings |
| Yu et al., 2015 | 3D weft knitted spacer fabrics | Pressure gloves for hypertrophic scars |
| Abou-Taleb, 2014 | 3D weft knitted spacer fabrics | Knee braces |
| Brisa, Helbig and Kroll, 2015 | 3D warp knitted spacer fabrics | Mattresses |
| Fournier et al., 2014 | 3D warp knitted spacer fabrics with elastic nitinol wires | Orthopedic implant coating material for hip and knee replacements |
| Yick et al., 2014 | 3D weft knitted spacer fabrics | |

| | |
|-----------------------|--------------------------------|
| Ghorbani et al., 2013 | Neoprene-spacer fabrics |
| Luximon, 2012 | 3D warp knitted spacer fabrics |

- Neoprene foam + 3D warp knitted spacer fabrics
- Are more durable
 - Are more permeable to moisture
 - Have better comfort and stronger performance



Proposed Neoprene-spacer fabric structure

Source from: Ghorbani, E., Hasani, H., Rafeian, H. and Hashemibeni, B. 2013 'Analysis of the Thermal Comfort and Impact Properties of the Neoprene-Spacer Fabric Structure for Preventing the Joint Damages', *International journal of preventive medicine*, 4(7), pp.761.

Orthopedic implant coating

Discussion

- Elastic nitinol wires + 3D warp knitted spacer fabrics
- Facilitate the ingrowth of bone
 - Reduced micro-motion,
 - Improved osseointegration
 - Provide stronger implant fixation in vivo

Viju et al., 2012

3D knitted spacer fabrics

Orthopedics, decubitus prevention

Bartels, 2011

bandages

Trümper et al., 2011

Davies and Williams, 2009

ontinence products

Lee, Rajendran and

Anand, 2009

chronic venous leg ulcers

Ye, Hu and Feng, 2008

rials

Möhring and Schwabe, 2008

acts for hypothermia prevention

Milosavljević and Škundrić, 2007

Knee and hip implants with eXalt coating

bandages

Pereira et al., 2006

Helde et al., 2005

Helde, Schwabe and Möhring, 2005

Source from: Fournier, E., Devaney, R., Palmer, M., Kramer, J., El Khaja, R. and Fonte, M. 2014 'Superelastic Orthopedic Implant Coatings', *Journal of Materials Engineering and Performance*, 23(7), pp.2464-2470.

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raction bandages



5. Conclusion

5. Conclusion

- Excellent and versatile physical properties of 3D knitted spacer fabrics
- 3D knitted spacer fabrics alone/ combined with other materials
- Bandages, mattresses, padding, orthopedic materials, pressure therapy garments, absorbent medical textiles, life saving products, orthopedic implant coating materials

References

- Abou-Taleb, H.A. (2014) 'Spacer fabrics for soft but strong knee braces', *Textile Asia*, 45(2), pp. 37-42.
- Abounaim, M., Hoffmann, G., Diestel, O. and Cherif, C. (2010) 'Thermoplastic composite from innovative flat knitted 3D multi-layer spacer fabric using hybrid yarn and the study of 2D mechanical properties', *Composites Science and Technology*, 70(2), pp. 363–370.
- Armakan, D. M. and Roye, A. (2009) 'A study on the compression behavior of spacer fabrics designed for concrete applications', *Fiber and Polymers*, 10(1), pp. 116-123.
- Bagherzadeh, R., Montazer, M., Latifi, M., Sheikhzadeh, M. and Sattari, M. (2007) 'Evaluation of Comfort Properties of Polyester Knitted Spacer Fabrics Finished with Water Repellent and Antimicrobial Agents', *Fibers and Polymers*, 8(4), pp. 386-392.
- Bartels, V. (ed.) (2011) *Handbook of medical textiles*. Elsevier, 38-79.
- Brisa, V. J. D., Helbig, F. and Kroll, L. (2015) 'Numerical characterisation of the mechanical behaviour of a vertical spacer yarn in thick warp knitted spacer fabrics', *Journal of Industrial Textiles*, 45(1), pp. 101-117.
- Bruer, S. M. and Smith, G. (2005) 'Three-Dimensionally Knit Spacer Fabrics: A Review of Production Techniques and Applications', *Journal of Textile and Apparel Technology and Management*, 4(4), pp. 1-31.
- Davies, A. and Williams, J. (2009) 'The use of spacer fabrics for absorbent medical applications', *Journal of Fiber Bioengineering and Information*, 1(4), pp. 321-329.
- EC21 Inc. (2013). Changzhou Wujin Yongguang Machinery Co., Ltd.
http://yongguang123.en.ec21.com/Ge2291B_High_Speed_Double_Needle--4783042_4783043.html
(Accessed March 10,2013)
- Fournier, E., Devaney, R., Palmer, M., Kramer, J., El Khaja, R. and Fonte, M. (2014) 'Superelastic Orthopedic Implant Coatings', *Journal of Materials Engineering and Performance*, 23(7), pp. 2464-2470.

References

- Ghorbani, E., Hasani, H., Rafeian, H. and Hashemibeni, B. (2013) 'Analysis of the Thermal Comfort and Impact Properties of the Neoprene-Spacer Fabric Structure for Preventing the Joint Damages', *International journal of preventive medicine*, 4(7), pp. 761.
- Google Scholar. Available at: <https://scholar.google.com/> (Accessed December 2015).
- Helde, M. and Moehring, U. (2003) '3D effects: Pressure relief, microclimate, support', *Kettenwirk-Praxis*, 36 (1), pp. 20-22.
- Helde, M., Möhring, U. and Schwabe, D. (2004) 'Compression bandages - A new 3D product puts on the pressure', *Kettenwirk-Praxis*, (4), pp. 16-18.
- Heide, M., Möhring, U., Schürer, M., Hänsel, R. and Richter, M. (2005) '3D warp-knitted fabrics improve orthopaedic shoes even more', *Kettenwirk-Praxis*, (4), pp. 13-15.
- Helde, M., Schwabe, D. and Möhring, U. (2005) 'Reusable 3D-knitted elastic short traction bandages [Wiederverwendbare 3D-gewirkte elastische Kurzzugbinden]', *Melliand Textilberichte*, 86(11-12), pp. 829-830+E186.
- Kanakaraj, P. and Anbumani, N. (2007). '3D knitted spacer fabrics and their applications', *Melliand International*, 13(1), pp. 47.
- Lee, G., Rajendran, S. and Anand, S. (2009) 'New single-layer compression bandage system for chronic venous leg ulcers', *British journal of nursing (Mark Allen Publishing)*, 18 (15), pp. S4-18.
- Luximon, A. (ed.) (2013) *Handbook of footwear design and manufacture*. Elsevier.
- Milosavljević, S. and Škundrić, P. (2007) 'Contribution of textile technology to the development of modern compression bandages', *Chemical Industry and Chemical Engineering Quarterly*, 13(2), pp.88-102.
- Möhring, U. and Schwabe, D. (2008) '3D thermal fabrics prevent the body from excessive cooling during surgical operations', *Kettenwirk-Praxis*, (1), pp. 23-24.
- Pereira, S., Anand, S.C., Rajendran, S. and Wood, C. (2006) 'Novel 3D warp knits for knee braces', *KNITTING INTERNATIONAL-LEICESTER-*, 113(1342), pp. 32.

References

- Scopus. Available at: <http://www.scopus.com/> Accessed December, 2015.
- Tanaka, K., Saura, R., Houraiya, K. and Tanimura, H. 2009 'A simple and useful hand orthosis for patients with amyotrophic lateral sclerosis: a simple web spacer for thumb opposition weakness', *Disability and Rehabilitation: Assistive Technology*, 4(5), pp.364-366.
- Tong, S. F., Yip, J., Yick, K. L. and Yuen, C. W. M. (2015) 'Exploring use of warp-knitted spacer fabric as a substitute for the absorbent layer for advanced wound dressing', *Textile Research Journal*, 85(12), pp. 1258-1268.
- Trümper, W., Sachse, C., Diestel, O. and Cherif, C. (2011) 'Innovative flat-knitted spacer fabrics for orthoses', *Technische Textilien*, 54 (4), pp. E171-E173.
- Viju, S., Parthiban, M., Srikrishnan, M.R. and Thilagavathi, C. (2012) 'Versatile applications of knitted spacer fabrics', *Melliand International*, 18 (2), pp. 120-121.
- Lo, W.T., 2014. *Development of plantar pressure relieving orthotic insoles for people with diabetes* (Doctoral dissertation, The Hong Kong Polytechnic University).
- Ye, X., Fanguero, R., Hu, H. and Araújo, M. D. (2007) 'Application of warp-knitted spacer fabrics in car seats', *Journal of the Textile Institute*, 98(4), pp. 337-344.
- Ye, X., Hu, H. and Feng, X. (2008) 'Development of the warp knitted spacer fabrics for cushion applications', *Journal of Industrial Textiles*, 37(3), pp. 213-223.
- Yick, K.L., Lo, W.T., Yu, A., Tse, L.T., Ng, S.P. and Yip, J. (2014) 'Study of three-dimensional weft-knitted spacer fabrics for clinical applications', *Textile Bioengineering and Informatics Symposium Proceedings 2014 - 7th Textile Bioengineering and Informatics Symposium, TBIS 2014, in conjunction with the 5th Asian Protective Clothing Conference, APCC 2014*, pp. 219-224.
- Yip, J. and Ng, S.P. (2008) 'Study of three-dimensional spacer fabrics: Physical and mechanical properties', *Journal of materials processing technology*, 206, pp. 359–364.
- Yu, A., Yick, K. L., Ng, S. P. and Yip, J. (2015) 'Orthopaedic textile inserts for pressure treatment of hypertrophic scars', *Textile Research Journal*, 0040517515573409.

Thank you

Q & A