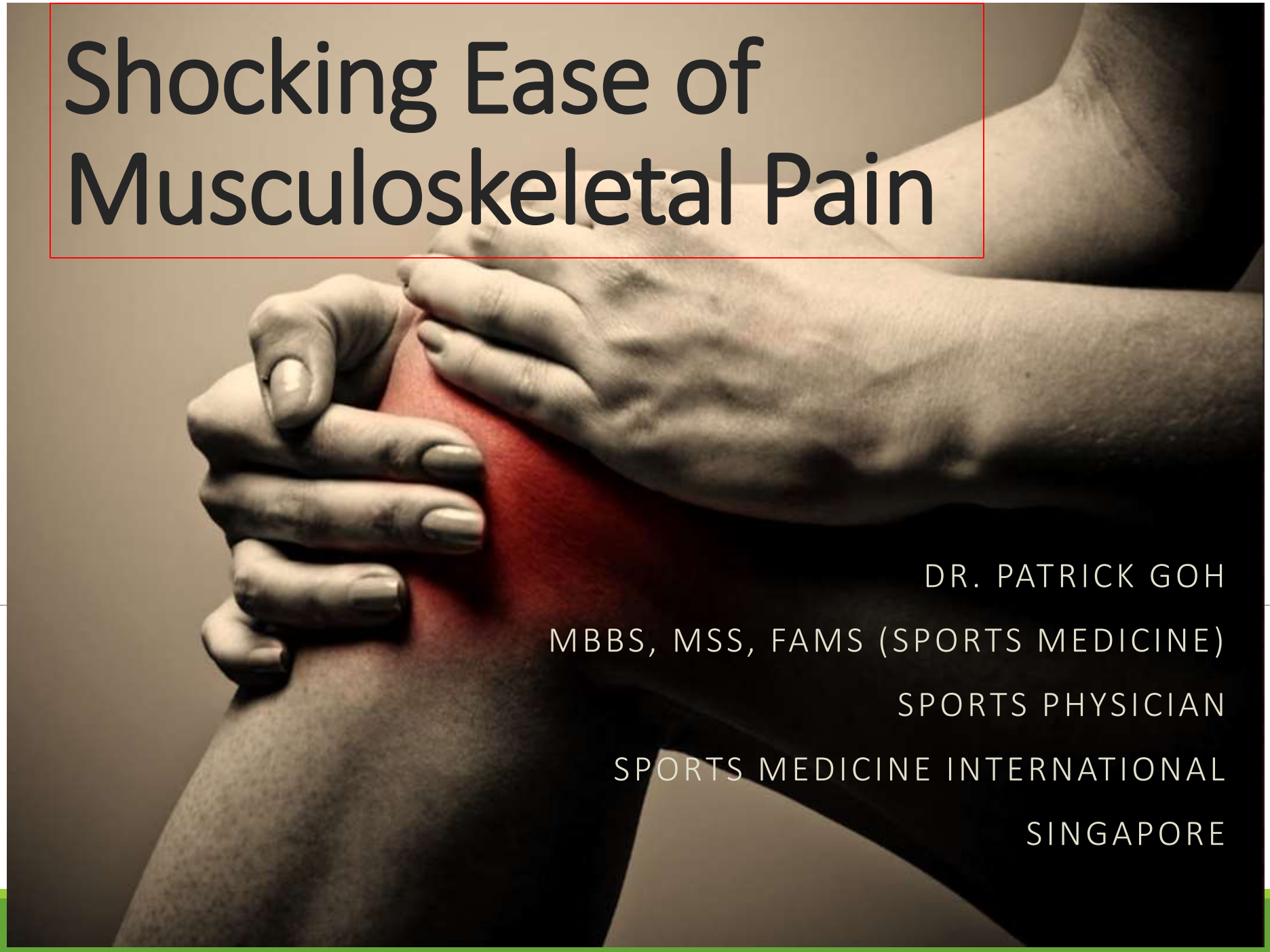
Shocking Ease of Musculoskeletal Pain



DR. PATRICK GOH

MBBS, MSS, FAMS (SPORTS MEDICINE)

SPORTS PHYSICIAN

SPORTS MEDICINE INTERNATIONAL

SINGAPORE

Sports Medicine International

Shockwave History – in Orthopaedics

1985 - first experiments to investigate the influence of shock waves on bones. (because of apprehension that shock waves could damage the hip when treating lower urinary tract stones)

- Discovery of osteogenic potential
- Stimulation of osteoblasts

Early 90's - first reports on shock wave therapy on tendinitis calcarea

ISMST Consensus: 38+8 Indications for SWT

1. Approved standard indications

1.1. Chronic Tendinopathies
1.1.1. Calcifying tendinopathy of the shoulder
1.1.2. Lateral epicondylopathy of the elbow (tennis elbow)
1.1.3. Greater trochanter pain syndrome
1.1.4. Patellar tendinopathy
1.1.5. Achilles tendinopathy
1.1.6. Plantar fasciitis, with or without heel spur
1.2. Bone Pathologies
1.2.1. Delayed bone healing
1.2.2. Bone Non-Union (pseudarthroses)
1.2.3. Stress fracture
1.2.4. Avascular bone necrosis without articular derangement
1.2.5. Osteochondritis Dissecans (OCD) without articular derangement
1.3. Skin Pathologies
1.3.1. Delayed or non-healing wounds
1.3.2. Skin ulcers
1.3.3. Non-circumferential burn wounds

2. Common empirically-tested clinical uses

2.1. Tendinopathies
2.1.1. Rotator cuff tendinopathy without calcification
2.1.2. Medial epicondylopathy of the elbow
2.1.3. Adductor tendinopathy syndrome
2.1.4. Pes-Anserinus tendinopathy syndrome
2.1.5. Peroneal tendinopathy
2.1.6. Foot and ankle tendinopathies
2.2. Bone Pathologies
2.2.1. Bone marrow edema
2.2.2. Osgood Schlatter disease: Apophysitis of the anterior tibial tubercle
2.2.3. Tibial stress syndrome (shin splint)
2.3. Muscle Pathologies
2.3.1. Myofascial Syndrome
2.3.2. Muscle sprain without discontinuity
2.4. Skin Pathologies
2.4.1. Cellulite

3. Exceptional indications – expert indications

3.1. Musculoskeletal pathologies
3.1.1. Osteoarthritis
3.1.2. Dupuytren disease
3.1.3. Plantar fibromatosis (Ledderhose disease)
3.1.4. De Quervain disease
3.1.5. Trigger finger
3.2. Neurological pathologies
3.2.1. Spasticity
3.2.2. Polyneuropathy
3.2.3. Carpal Tunnel Syndrome
3.3. Urologic pathologies
3.3.1. Pelvic chronic pain syndrome (abacterial prostatitis)
3.3.2. Erectile dysfunction
3.3.3. Peyronie disease
3.4. Others
3.4.1. Lymphedema

4. Experimental Indications

4.1. Heart Muscle Ischemia
4.2. Peripheral nerve lesions
4.3. Pathologies of the spinal cord and brain
4.4. Skin calcinosis
4.5. Periodontal disease
4.6. Jawbone pathologies
4.7. Complex Regional Pain Syndrome (CRPS)
4.8. Osteoporosis

https://www.shockwavetherapy.org/about-eswt/indications/

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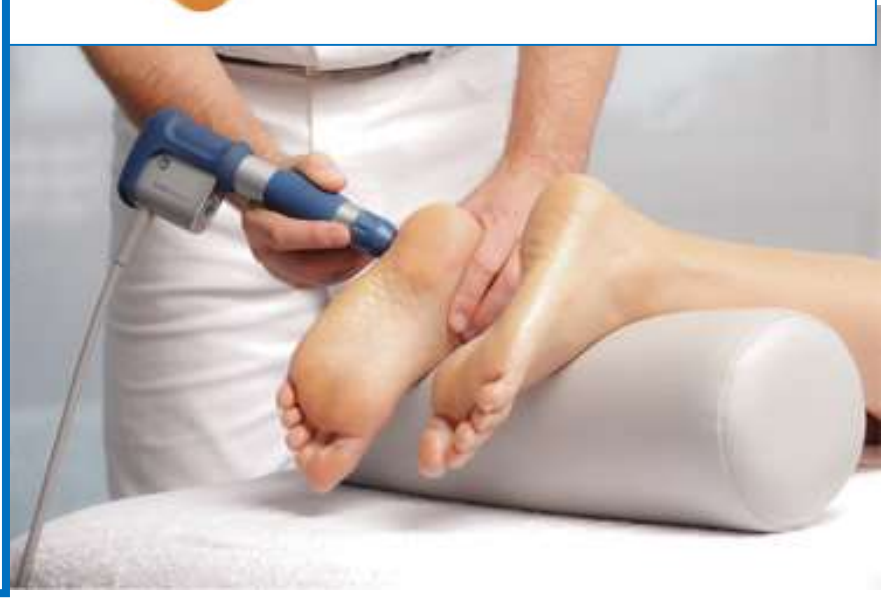
“Focussed” Shockwave

“Radial” Shockwave

Focussed ESWT (Extracorporeal Shock Wave Therapy)


DMT
Dornier MedTech

“Radial” Shock Wave Therapy



“Radial Shockwave”

≠

“Focussed Shockwave”

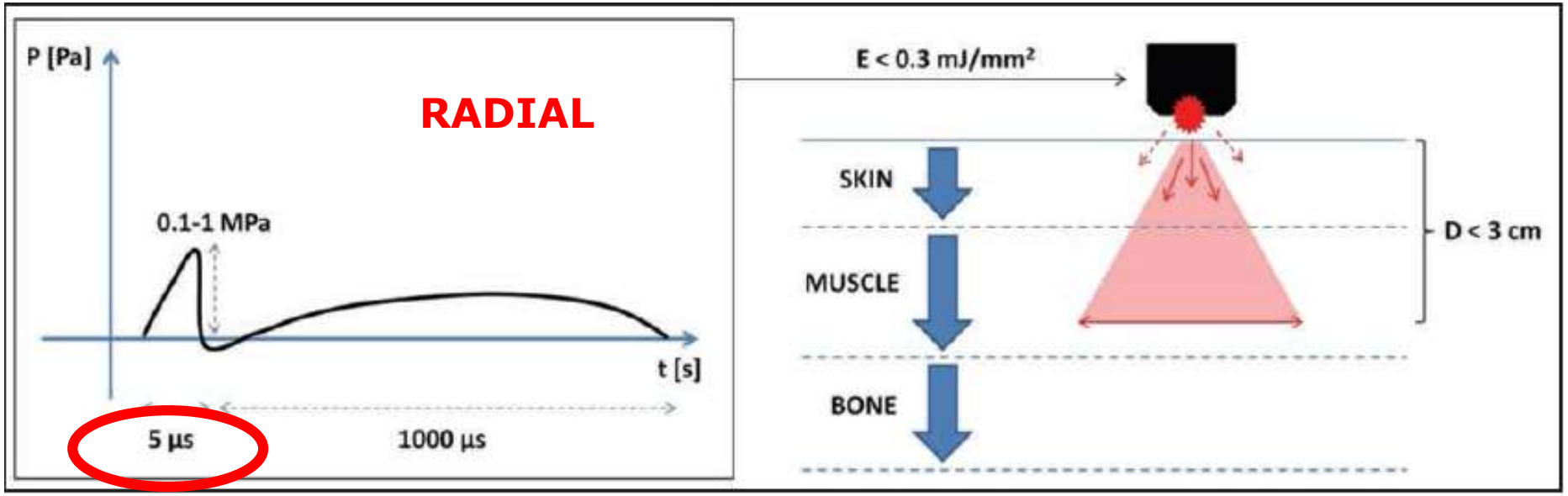


Figure 1. Schematic illustration of wave propagation with physical characteristics of radial extracorporeal shock wave therapy (ESWT).

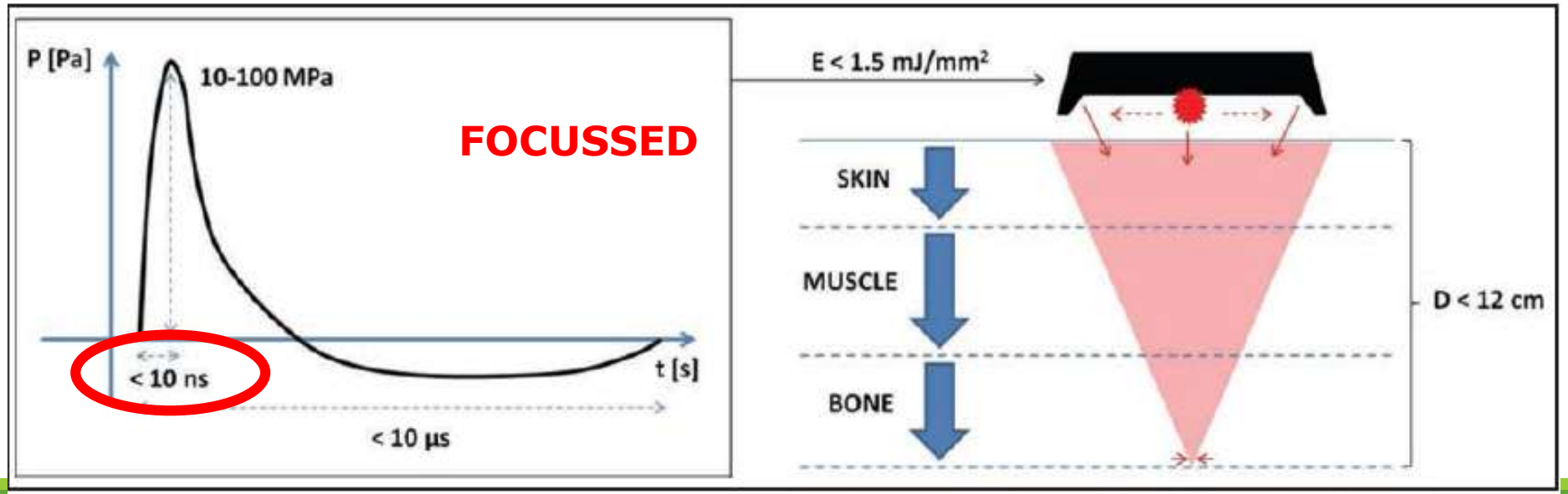


Figure 2. Schematic illustration of wave propagation with physical characteristics of focused ESWT.

Focussed ESWT vs. Radial SWT

Focussed Shockwaves travel faster than the speed of sound, or 1500 meters per second. "Shock" of the shockwave is generated, from breaking the sound barrier.

Radial Shockwaves travel at speeds of approximately 10 meters per second. This speed does not break the sound barrier, and hence, no actual shockwave is generated

Biological effects differ

Most research on Shock Wave used Focussed SW

Shock Wave Therapy induces neovascularisation at the tendon-bone junction. A study in rabbits

Wang CJ et al. Journal of Orthopaedic Research 21, 984-989 (2003)

50 NZ Rabbits, Right TA - ESWT, Left TA- Control

Biopsy @ 0, 1, 4, 8, 12 weeks

Staining of neo-vessels by hematoxylin-eosin stain

Immunohistochemical staining

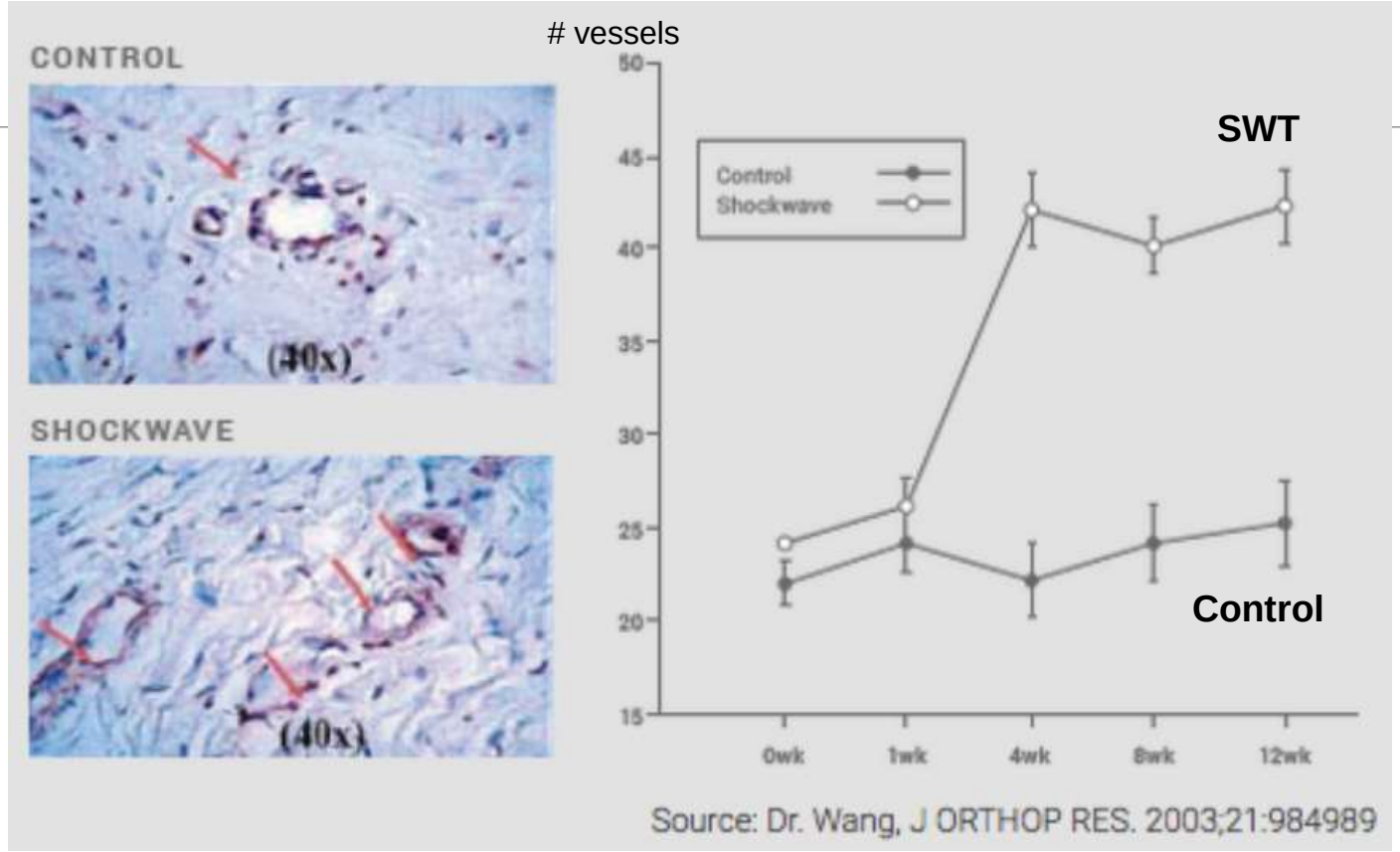
- PCNA (Proliferating Cell Nuclear Antigen)
- VEGF (Vessel Endothelial Growth Factor)
- eNOS (Endothelial NO Synthase)

Table 1
The effect of shock wave therapy on the ingrowth of neo-vessels

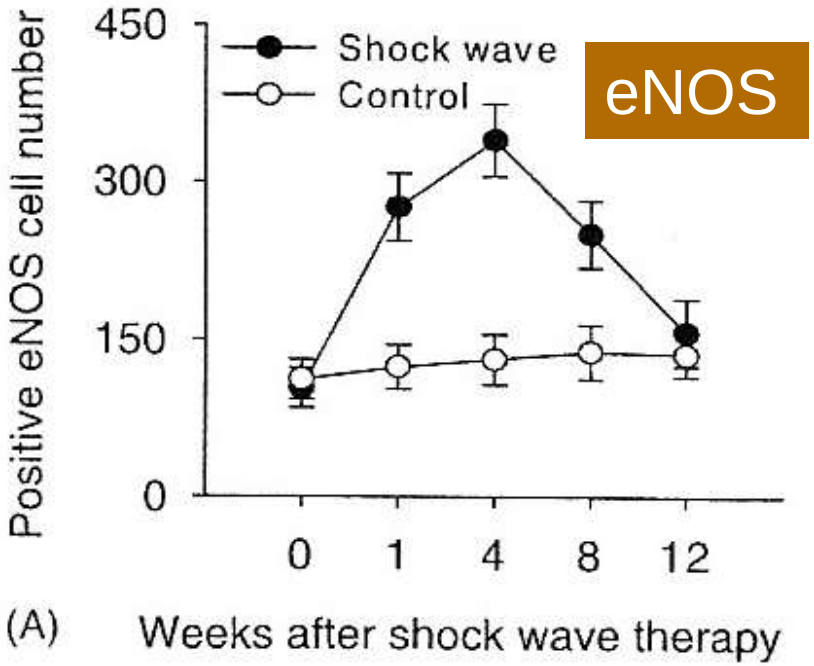
Time	Control ($N = 50$)	Shock wave ($N = 50$)	P-value*
0-Week ($N = 10$)			
Mean ± SD	22 ± 3	24 ± 4	0.93
1-Week ($N = 10$)			
Mean ± SD	24 ± 4	26 ± 5	0.95
P-value**	0.86	0.92	
4-Week ($N = 10$)			
Mean ± SD	22 ± 5	42 ± 4	0.024
P-value**	0.71	0.0017	
8-Week ($N = 10$)			
Mean ± SD	24 ± 5	40 ± 5	0.021
P-value**	0.81	0.0025	
12-Week ($N = 10$)			
Mean ± SD	25 ± 6	42 ± 4	0.017
P-value**	0.92	0.0082	

P-values are based on Mann–Whitney test: (*) comparison of control with shock wave therapy; (**) comparison of 0-week with 1-, 4-, 8- and 12-week.

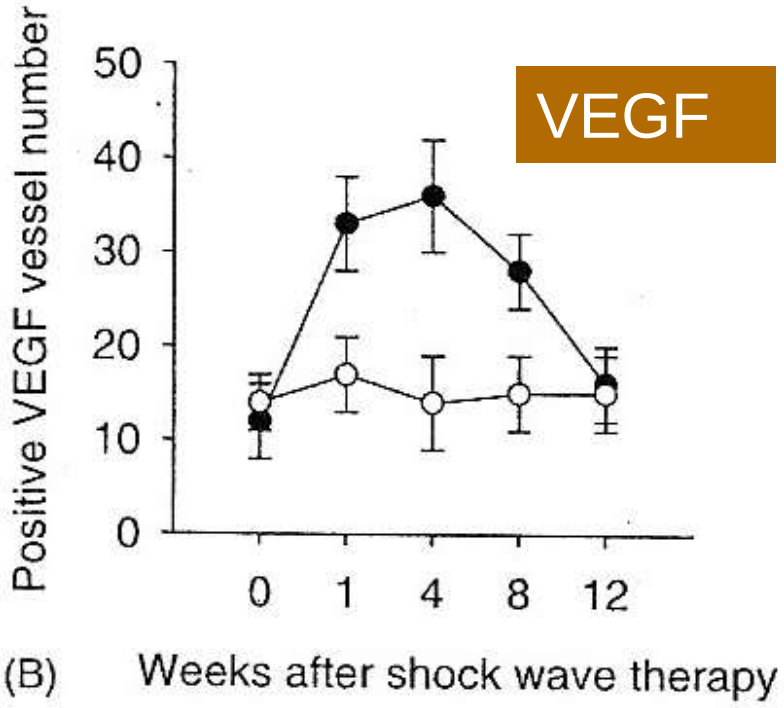
Shockwaves increase number of blood vessels



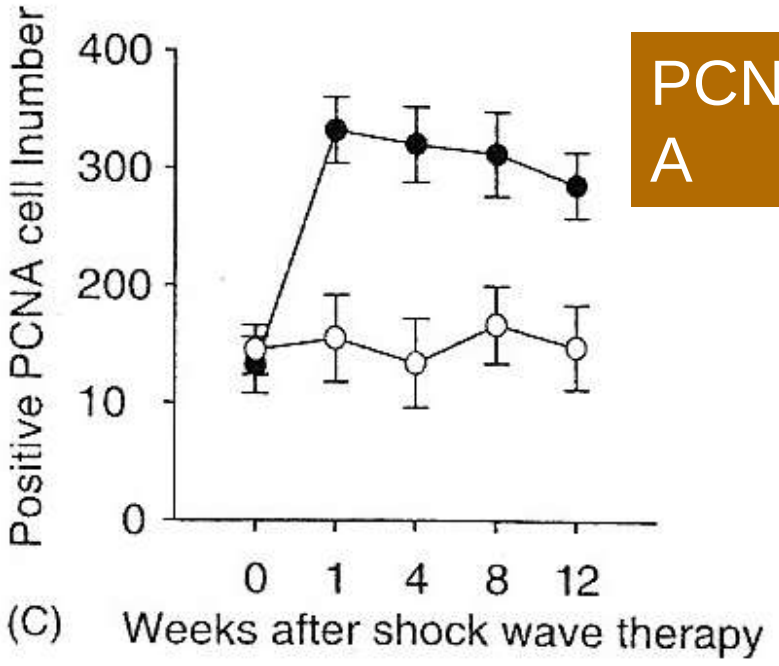
500SW @ 0.12mJ/mm^2 delivered to right Achilles tendon near insertion site at d0 (fluoroscopic verification; NZ white rabbit). Tendons were dissected and examined at different time points.



eNOS



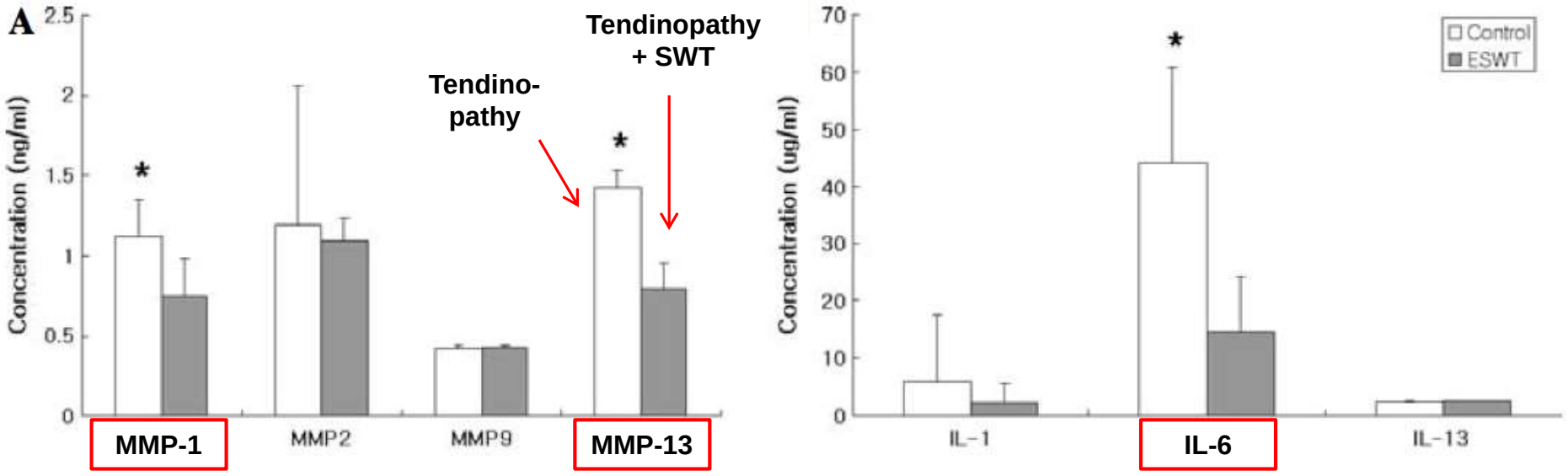
VEGF



PCN
A

Shockwaves decrease tendon inflammation

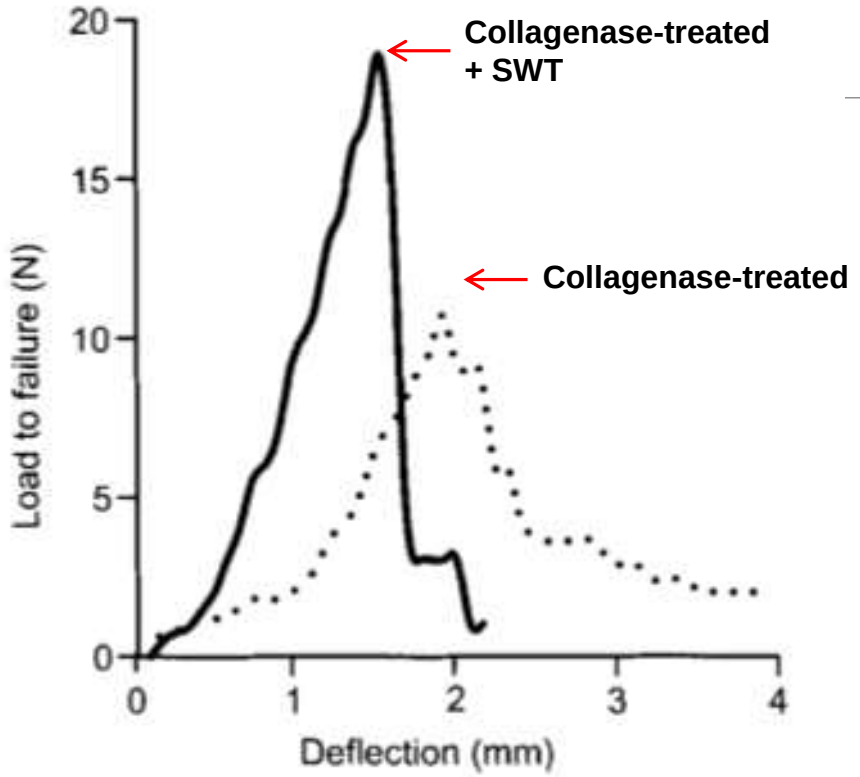
Decreased inflammation markers after shockwave therapy



Human diseased Achilles tendon was surgically obtained. Tenocytes were cultured for 10-14 days, then exposed to SW @ 0.17 mJ/mm^2. Media was collected 72h after SW exposure, and cytokines were quantified by ELISA.

Han et al. Foot Ankle Int. 2009 Feb;30(2):93-8.

Shockwaves restore tendon strength after injury



Sprague-Dawley rats were injected with 250U collagenase near the osteotendinous junction of the left Achilles tendon. 200SW @ 0.16 mJ/mm^2 were delivered at d3. Tendons were excised and assessed 12wk after SWT (loading rate 20mm/min).

Chen et al. J Orthop Res. 2004 Jul;22(4):854-61.

Effect on nerves:

Trigger cumulative action potential

hyperpolarisation lasting 1 hr.

(Buch 1997)

Cutaneous Nerves in Rat Skin (Ohtiri et al 2002)

- Rapid degeneration of cutaneous nerves
- re-innervation after 2 weeks
- Early pain decrease due to degeneration of sensory fibres

Shockwave therapy for Sports Medicine

Shockwave energy

Nerve Stimulation
Fracture Calcifications
Vasodilation
Growth Factors
Angiogenesis

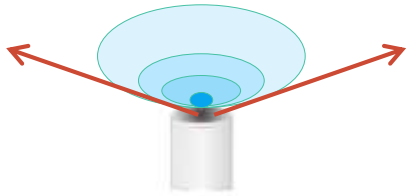
Biological effects

Pain Relief
Calcium Absorption
Tissue Healing
(Pro-Regeneration)

Clinical results

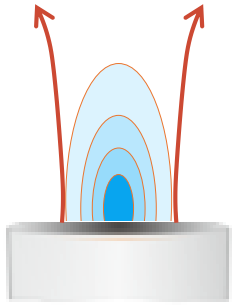
Shockwave Focusing

Unfocused



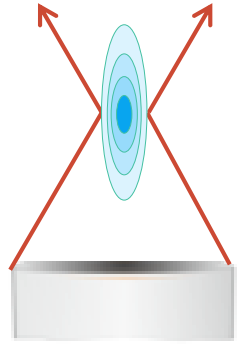
- Optimized for surface treatment
- **Wide focal zone**
- **Poor energy penetration**

Soft Focus



- **Optimized for <u>both</u> surface and deep tissue treatment**
- ***Wide focal zone***
- ***Good energy penetration***

Focused



- Optimized for deep tissue treatment
- **Narrow focal zone**
- **Good energy penetration**

High energy density

Low energy density

Energy boundaries

Aries vs EPOS vs Gemini: Focal area

8.0 cm

17.0 cm

Energy Levels
(Rompe, Bachmann)

Low	0.08 - 0.28 mJ/mm^2
Medium	0.28 - 0.60 mJ/mm^2
High	> 0.60 mJ/mm^2

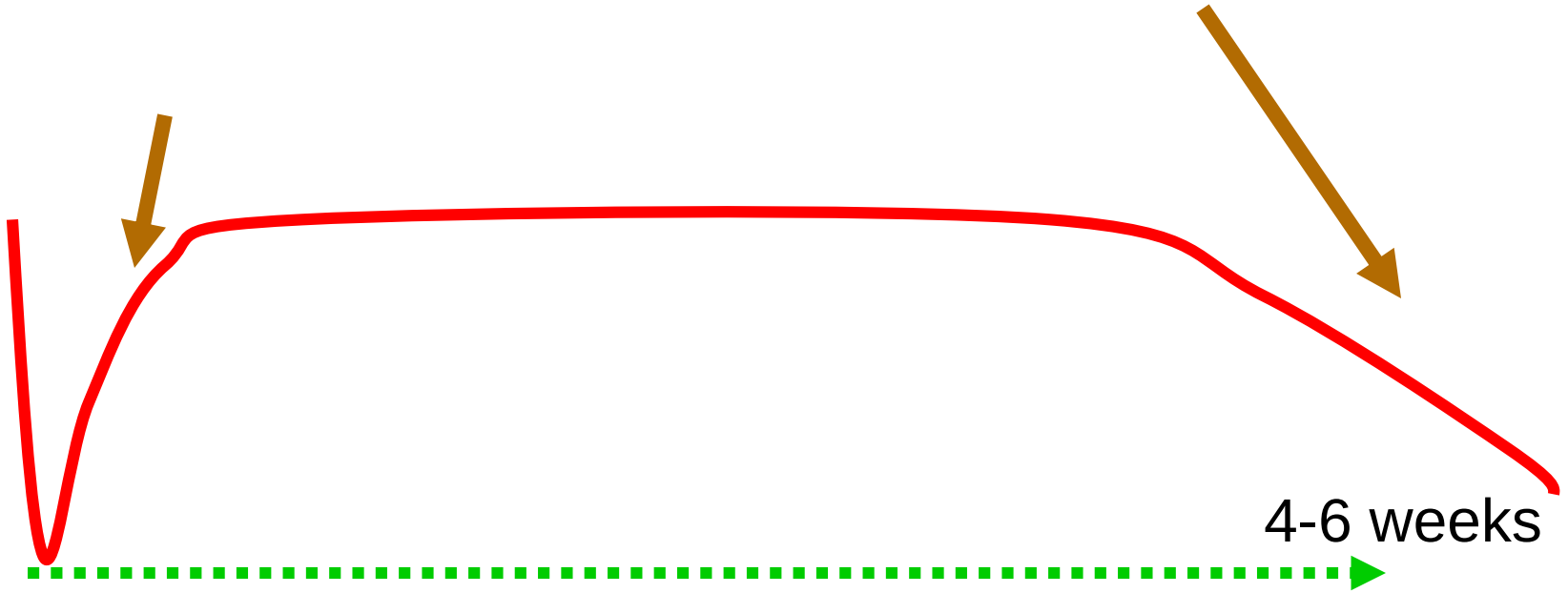
Aries vs EPOS vs Gemini

Dornier *ARIES*			Dornier *EPOS*			Dornier *Gemini*		
Energy Level	ED [mJ/mm²]	E(12mm) [mJ]	Energy Level	ED [mJ/mm²]	E(12mm) [mJ]	Energy Level	ED [mJ/mm²]	E(12mm) [mJ]
1	0.010	0.28	1	0.13	3.8	1	0.35	16
2	0.013	0.85	2	0.17	5.8	2	0.50	22
3	0.028	2.0	3	0.22	7.8	3	0.65	28
4	0.051	3.4	4	0.32	11.3	4	0.80	37
5	0.062	4.7	5	0.43	14.8	5	0.89	41
6	0.084	5.8	6	0.53	17.7	6	0.98	48
7	0.096	6.6	7	0.64	20.5	7	1.06	55
8	0.117	8.1	8	0.82	23.9	8	1.13	61
9	0.130	9.2	9	1.00	27.3	9	1.20	68
10	0.150	10.5				10	1.28	76
11	0.169	11.8				11	1.34	82
12	0.179	12.5				12	1.41	89
13	0.200	14.1				13	1.47	96
14	0.212	14.9				14	1.54	104
15	0.224	15.7				15	1.60	110
16	0.249	17.5						
17	0.262	18.5						
18	0.280	19.0						
19	0.290	20.5						
20	0.306	21.6						

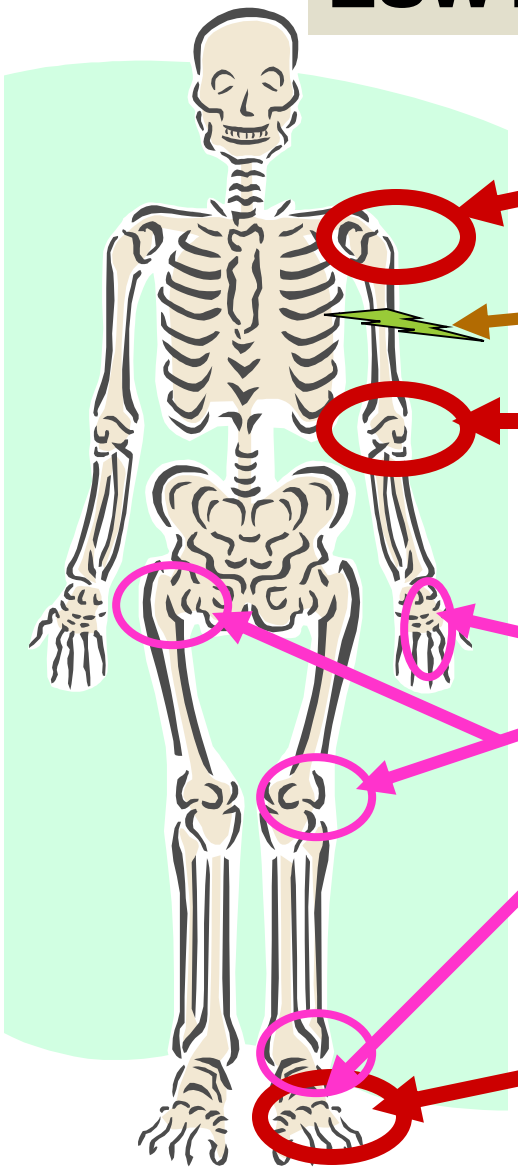
Bimodal Pain relief Response after ESWT (Odgen 2002)

Pain reduction 0-4 days:
Nerve damage /
hyperstimulation analgesia

Pain reduction after 1 month:
Angiogenesis and tissue healing



ESWT - MUSCULOSKELETAL USES



ROTATOR CUFF
Calcific Tendinosis

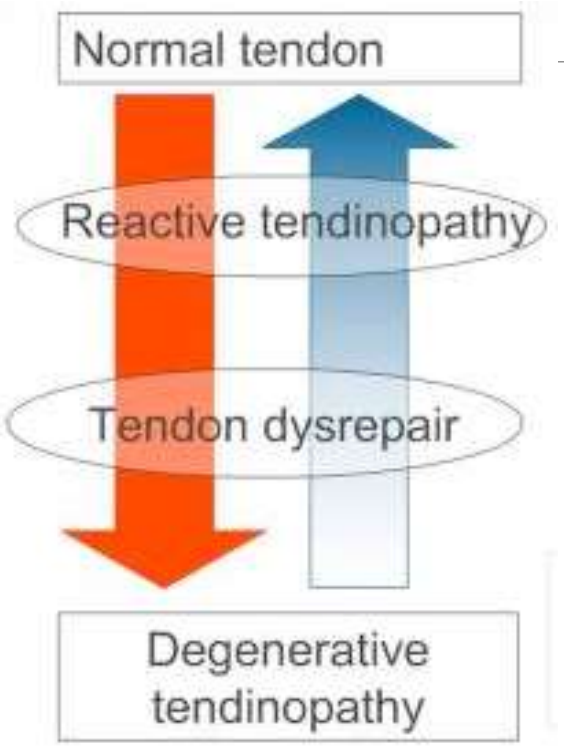
FRACTURES – Delayed or Non-Union

EPICONDYLITIS
(Tennis/Golfer's Elbow)

Other Tendinosis:
Knee, Achilles, Wrist/Hand, Hip

PLANTAR FASCIITIS
(Heel Spur Pain)

Tendinopathy



Over-loading/ insufficient rest/ genetics/ drugs:

- Inflammatory environment
- Local hypoxia
- Collagen degradation > synthesis

Tendinopathy

- Disrupted collagen alignment
- Decreased load bearing
- Pain

Tendinopathy: Current treatment options

Medications
- analgesics, muscle relaxants, NSAIDs, steroid injections

Orthotics
- Splints, braces

Physical and Occupational Therapy
- Strengthening, stretching, patient education

Shockwave therapy

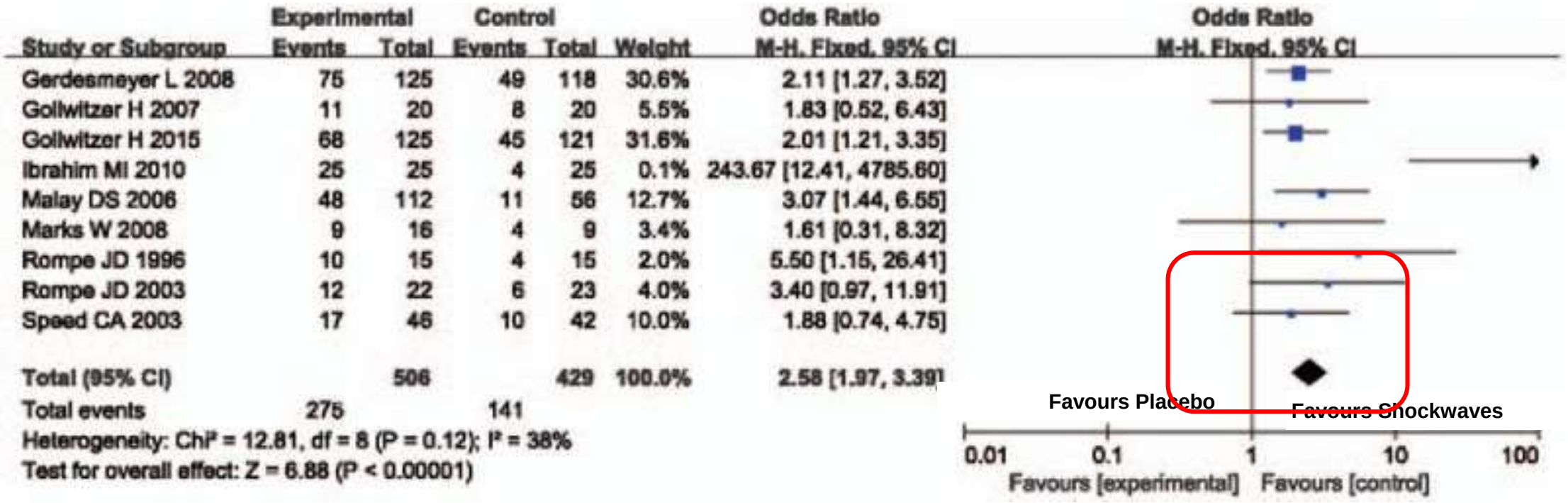
Biologics
- Eg. Platelet-rich plasma

Surgery

J Foot Ankle Surg. 2010 May-J

Meta-analysis of RCTs: Extracorporeal shock wave therapy is effective in treating **chronic plantar fasciitis**

Fig 4. Forest plot of success rate of general ESWT in chronic plantar fasciitis.



Study or Subgroup	Experimental Events	Experimental Total	Control Events	Control Total	Weight	Odds Ratio M-H, Fixed, 95% CI
Gerdesmeyer L 2008	75	125	49	118	30.6%	2.11 [1.27, 3.52]
Gollwitzer H 2007	11	20	8	20	5.5%	1.83 [0.52, 6.43]
Gollwitzer H 2015	68	125	45	121	31.6%	2.01 [1.21, 3.35]
Ibrahim MI 2010	25	25	4	25	0.1%	243.67 [12.41, 4785.60]
Malay DS 2006	48	112	11	56	12.7%	3.07 [1.44, 6.55]
Marks W 2008	9	16	4	9	3.4%	1.61 [0.31, 8.32]
Rompe JD 1996	10	15	4	15	2.0%	5.50 [1.15, 26.41]
Rompe JD 2003	12	22	6	23	4.0%	3.40 [0.97, 11.91]
Speed CA 2003	17	46	10	42	10.0%	1.88 [0.74, 4.75]
Total (95% CI)		506		429	100.0%	2.58 [1.97, 3.39]
Total events	275		141			

Heterogeneity: $Chi^2 = 12.81$, $df = 8$ ($P = 0.12$); $I^2 = 38\%$

Test for overall effect: $Z = 6.88$ ($P < 0.00001$)

Therapeutic success was defined as a decrease in visual analogue scale (VAS) score from baseline larger than 50% or 60%, or VAS score of less than 4 after intervention, according to the included studies

Sun et al. Medicine (Baltimore). 2017 Apr; 96(15): e6621

Am J Sports Med. 2015 Mar;43(3):752-61. doi: 10.1177/0363546514531911. Epub 2014 May 9.

The effectiveness of extracorporeal shock wave therapy in lower limb tendinopathy: a systematic review.

Mani-Babu S[1], Morrissey D[2], Waugh C[1], Screen H[3], Barton C[4].

CONCLUSION:

"Extracorporeal shock wave therapy is an effective intervention and should be considered for **Greater Trochanter Pain Syndrome, Patellar Tendinopathy, and Archilles Tendinopathy** particularly when other nonoperative treatments have failed."

ARIES for Tendinitis

1. **Identify** the tendon and tender spot
   - History, physical exam, palpation and ultrasound
2. Add ultrasound gel, and apply shockwaves to the tendon
   - **Position** patient for comfort, good access, with the tendon gently extended
   - Start at low energy (L3), and **identify tender point**(s) by patient feedback
   - **Increase to therapeutic level** (L4-10 based on pain tolerance). ~1000 SW at the tender point, or until pain is much reduced. Repeat scan to find next point.
3. (optional) Apply shockwaves to the affected muscle
   - "massage" muscle to stimulate lymphatic drainage, ~1000 SW at therapeutic lvl

Energy Density: 0.05 – 0.15 mJ/mm^2 (Level 4-10)
Number of shockwaves: 1000 SW per tender point
Interval: once / week, 3 - 6 sessions total
Anesthesia: none

https://www.youtube.com/watch?v=96eNiE-WHRQ

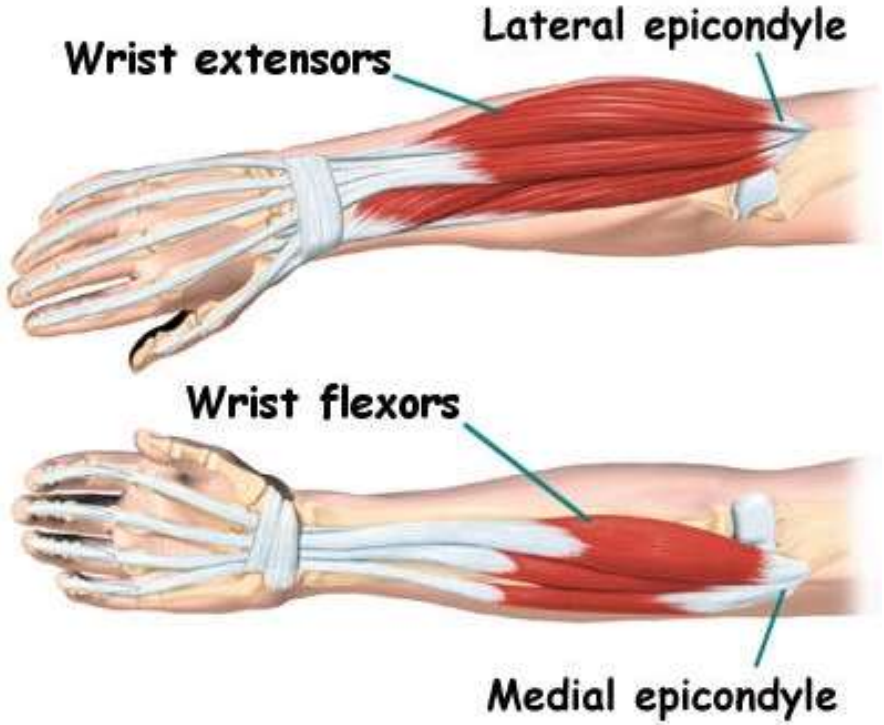
Dornier *Aries*

Each session: 4000SW @ Level 4-7
Interval: once/week, 3 sessions

Epicondylitis

Inflammation of the Epicondyle or the adjacent tissues

→ Tennis Elbow (Lateral Epicondyle)



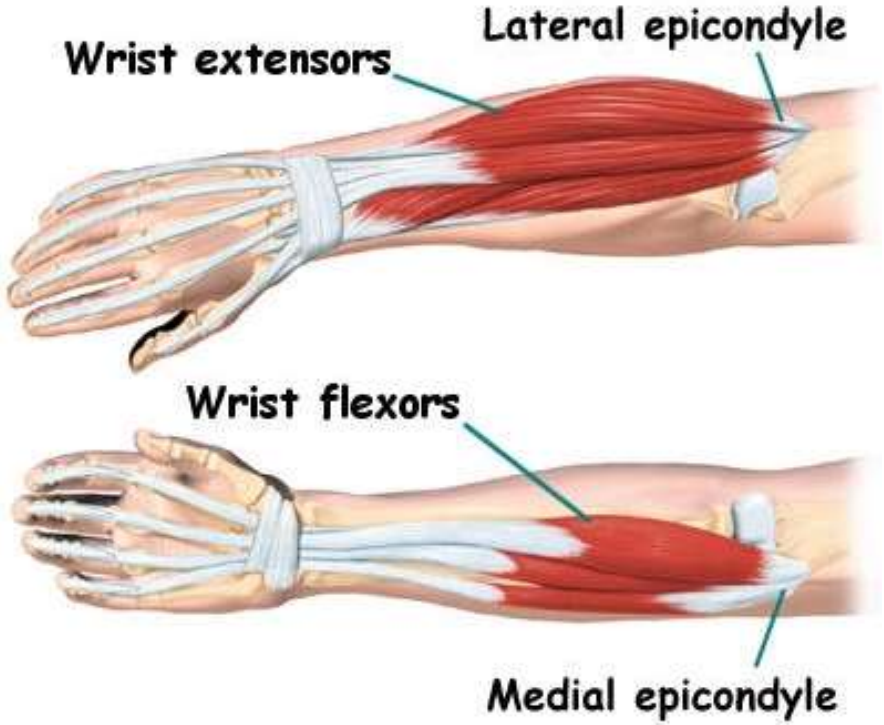
Dornier *Aries*

Each session: 4000SW @ Level 4-7
Interval: once/week, 3 sessions

Epicondylitis

Inflammation of the Epicondyle or the adjacent tissues

→ Golfer's Elbow (Medial Epicondyle)



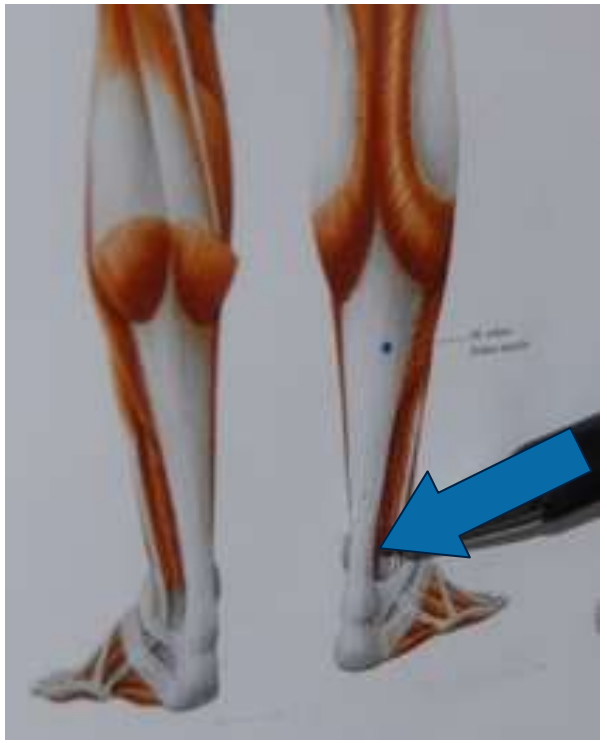
Dornier *Aries*

Each session: 4000SW @ Level 4-7
Interval: once/week, 3 sessions

Achillodynia

→ Inflammation of the Achilles Tendon or the Bursa connected to it

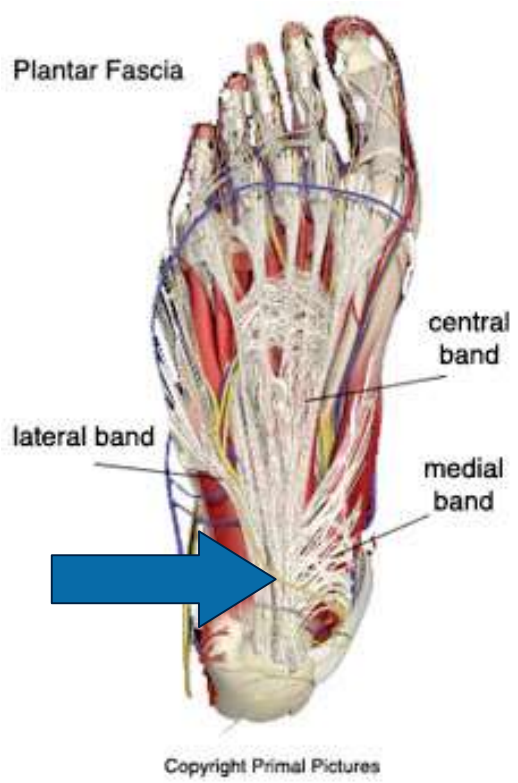
Example shown: Treatment near the tendon insertion



Dornier *Aries*

Each session: 4000SW @ Level 4-9
Interval: once/week, 3 sessions

- Plantar Fasciitis/Heel Spur
  - → Plantar Fasciitis: Inflammation of the Plantar Fascia
  - → Heel Spur: bony outgrowth of heel bone



Each session: 2000SW @ Level 8-12
Interval: once/ 1-2 wk, 2-3 sessions

Calcified Shoulder

→ Tendinopathy of the rotator cuff muscles, leading to calcifications in the tendon (shown: supraspinatus)

ESWT for the treatment of Chronic Calcifying Tendonitis of the Rotator Cuff

Gerdesmeyer, L. et al. JAMA Nov 2003

Double Blind RCT

144 patients

High Energy, Low Energy, Placebo

CONCLUSION:

- High & Low energy significantly less pain and reduced calcification.
- Effectiveness: High>Low energy

Contents lists available at ScienceDirect

International Journal of Surgery

journal homepage: www.journal-surgery.net

Review

Biological mechanism of shockwave in bone

Jai-Hong Cheng [a, b], Ching-Jen Wang [a, c, *]

[a] Center for Shockwave Medicine and Tissue Engineering, Kaohsiung Chang Gung Memorial Hospital and Chang Gung University College of Medicine, Kaohsiung, Taiwan
[b] Medical Research, Kaohsiung Chang Gung Memorial Hospital and Chang Gung University College of Medicine, Kaohsiung, Taiwan
[c] Department of Orthopedic Surgery, Kaohsiung Chang Gung Memorial Hospital and Chang Gung University College of Medicine, Kaohsiung, Taiwan

HIGHLIGHTS

- ESWT is a novel method in musculoskeletal disorders and other disease.
- The biologied effects of ESWT may be through mechanotransduction.
- Applications of ESWT are increasing.
- ESWT promotes tissue regeneration, wound healing, angiogenesis, bone remodeling, and anti-inflammation.

ESWT and Bone....

Upregulation of Growth Factors eNOS, VEGF, PCNA, TGFB-1, BMP2 *(CJ Wang, 2008)*

Triggers cascade of angiogenic and osteogenic transcription factors (Cbfal/Runx2, HIF-1a and VEGF) in osteoblast cells *(FS Wang et al, 2002, 2004)*

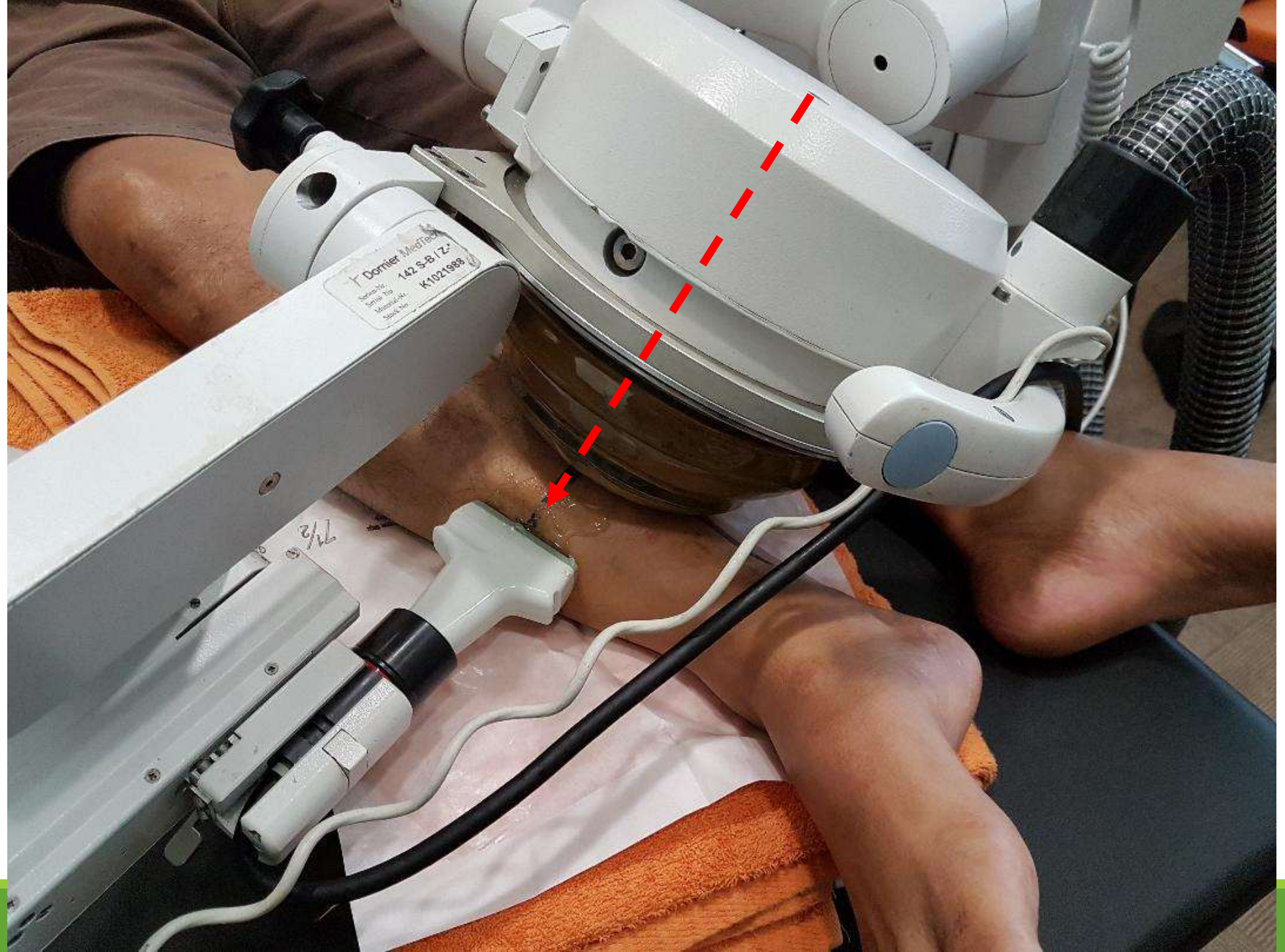
induces nitric oxide (NO) elevation that promotes proliferation and differentiation of human osteoblasts *(Martini et al,2003)*

ESWT and BONE

ESWT reduces the healing time of nonunions (Valchanou et al. 1991; Johannes et al. 1994; Haupt 1997)

High energy induces periosteal detachment and trabecular fractures with hemorrhages, which in turn stimulate callus formation and subsequent fracture healing (Narasakiet al. 2003; Bara et al. 2000; Bulut et al. 2006)

Low-middle energy induces mesenchymal stem cell recruitment and differentiation into osteoblasts for bone formation (Martini et al. 2003; Chen et al. 2004; Aicher et al. 2006).


Dornier MedTech
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ISMST Guidelines – Usage in Bone

1.2. Bone Pathologies – Standard Indications

1.2.1. Delayed bone healing
1.2.2. Bone Non-Union (pseudarthroses)
1.2.3. Stress fracture
1.2.4. Avascular bone necrosis without articular derangement
1.2.5. Osteochondritis Dissecans (OCD) without articular derangement

2.2. Bone Pathologies – Empirically Supported Indications

2.2.1. Bone marrow edema
2.2.2. Osgood Schlatter disease: Apophysitis of the anterior tibial tubercle
2.2.3. Tibial stress syndrome (shin splint)

Skin - Wound Healing

Before ESWT

After ESWT

1 session / week for 10 weeks. 1500 SW at Aries level 3.
Photos courtesy of Dr Patrick Goh, Camden Medical Centre

Extracorporeal Shock Wave Therapy in Myofascial Pain Syndrome of Upper Trapezius

(Hye Min Ji, et al. 2012, Ann Rehabil Med 2012; 36(5): 675-680)

Authors assessed the effect of ESWT (Dornier AR2) in myofascial pain syndrome of the upper trapezius in 20 patients using the visual analogue scale (VAS) and pressure threshold by digital algometer.

	Treated group	Control group
No of patients	10 each	
No of sessions	Twice weekly. Total of 4 sessions	
No of shockwaves	1000	
Energy level	0.056mJ/mm2	0.001mJ/mm2

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Result

	Treated group	Control group
VAS before treatment	4.91±1.76	4.89±1.76
VAS after treatment	2.27±1.27	4.44±2.13
Pressure threshold before	40.4±9.94 N	43.7±10.27 N
Pressure threshold after	61.2±12.16 N	45.0±9.17 N

VAS: 10 score is maximum pain that cannot be endured, and 0 score is no pain
Pressure threshold: subjective measurement with a digital algometer. Average of 3 meausrements.

ESWT is effective in the pain relieve of myofascial pain syndrome of the upper trapezius after four sessions of therapies in two weeks.

Aries Treatment Guide

Indication	Area of treatment	No of shockwaves	No of sessions	Energy level	Frequency
Plantar Fasciitis	Plantar fascia	4000	3	4 - 9	Once a week
Achillotendinitis	Tendon	4000	3	4 - 7	Once a week
Epicondylitis	Tendon	4000	3	4 - 7	Once a week
Calcific tendonitis of the shoulder	Calcification	2000	2 - 3	8 - 12	Once / 1-2 week
Achillotendinitis (Gastrocnemius m.)	Trigger points	1000/Trp Total: 4000-6000	6 - 12	As acceptable	2 times a week
M.Plantaris	Trigger points	1000/Trp Total: 4000-6000	6 - 12	As acceptable	2 times a week
M.Tibialis posterior	Trigger points	1000/Trp Total: 4000-6000	6 - 12	As acceptable	2 times a week
M.Quadr.plantaris	Trigger points	1000/Trp Total: 4000-6000	6 - 12	As acceptable	2 times a week

Thank You

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