

Appendix

TABLE E-1 Summary of Included Clinical Studies*

Type of Stimulation and Study	Level of Evidence	Indication Tested	No. of Patients	Outcome Measure	Result
Direct current					
Andersen ⁴⁴	I	Spinal fusion	84 elderly patients (43 direct current, 41 control)	Successful fusion	35% (15/43) fused with direct current stimulation, 37% (15/41) fused in control group with no stimulation
Rogozinski ⁴⁷	I	Spinal fusion	94 (53 direct current, 41 control)	Successful fusion	96.2% (51/53) successfully fused with stimulation, 85.4% (35/41) fused in control group with no stimulation
Kane ⁴⁶	I	Spinal fusion	59 (28 control, 31 direct current)	Successful fusion	53.6% (15/28) of control patients fused compared with 80.6% (25/31) of patients fused with direct current stimulation
Jenis ⁴⁵	I	Lumbar spinal fusion	61 (17 direct current, 22 pulsed electromagnetic field, 22 control)	Rate of fusion	Electrical stimulation did not significantly enhance fusion rate in instrumented lumbar arthrodesis
Steinberg ⁴⁸	II (control patients retrospectively compared)	Osteonecrosis of femoral head	116	Osteonecrosis radiographic progression and Harris hip score	Patients treated with direct current showed less radiographic osteonecrosis progression and achieved better Harris hip scores than control patients
Meril ⁴⁹	II	Spinal fusion	225 (122 direct current, 103 control)	Successful fusion	Fusion rate was 93% (113/122) in direct current group and 75% (77/103) in control group
Torben ⁶¹	II	Tibial nonunion	24 with direct current stimulation, 43 control	Time to union	Mean time to union of 2.4 months in direct current group and 3.6 months in control group
Brighton ³⁷	IV	Long-bone nonunion	80	Radiographic union	72.5% (58/80) healed
Brighton ³⁸	IV	Tibial nonunion	123	Radiographic union	87.0% (107/123) healed
Brighton ³⁹	IV	Long-bone nonunion	54	Radiographic union	72.2% (39/54) healed
Brighton ⁴⁰	IV	Long-bone nonunion	24	Radiographic union	62.5% (15/24) healed
Day ⁵¹	IV	Long-bone nonunion	16	Radiographic union	68.75% (11/16) healed
Dwyer ⁵²	IV	Spinal fusion	12	Successful fusion	91.7% (11/12) healed
Donley ⁶⁴	IV	Ankle fusion	13	Successful fusion	84.6% (11/13) healed
Esterhai ⁴¹	IV	Humeral nonunion	39	Radiographic union	43.6% (17/39) healed
Heppenstall ⁵³	IV	Tibial nonunion	40	Radiographic union	85.0% (34/40) healed
Kucharzyk ⁵⁴	IV	Spinal fusion	65	Successful fusion	95% (62/65) healed

Midis ⁶²	IV	Ankle fusion	10	Successful fusion	100% (10/10) fused
Paterson ²⁹	IV	Long-bone nonunion	84	Radiographic union	85.7% (72/84) healed
Paterson ⁵⁵	IV	Congenital pseudarthrosis	27	Radiographic union	74.1% (20/27) healed
Tejano ⁵⁶	IV	Spinal fusion	118	Successful fusion	90.7% (107/118) fused
Zichner ⁵⁷	IV	Long-bone nonunion	57	Radiographic union	93.0% (53/57) healed
Hughes ⁴²	IV	Long-bone nonunion	111	Radiographic union	84.7% (94/111) healed
Forsted ⁵⁸	IV	Long-bone nonunion	87	Radiographic union	80.5% (70/87) healed
Bora ⁵⁹	IV	Scaphoid nonunion	17	Radiographic union	70.6% (12/17) healed
Kleczynski ⁶⁰	IV	Long-bone nonunion	62	Radiographic union	93.5% (58/62) healed
De Vries ⁶³	IV	Ankle fusion	91	Successful fusion	52.7% (48/91) fused
Jorgensen ⁵⁰	IV	Fresh tibial fracture	28	Acceleration to healing	Stimulated patients experienced 30% acceleration in healing as determined by mechanically stressing the Hoffmann apparatus used for immobilization of the fracture
Capacitive coupling					
Goodwin ⁷⁰	I	Spinal fusion	179	Successful fusion	84.7% fused in capacitive coupling group, 64.9% fused in control group
Scott ⁶⁵	I	Long-bone nonunion	21	Radiographic union	60% (6/10) healed in capacitive coupling group and 0% (0/11) in control group
Benazzo ⁶⁹	IV	Stress fracture in athletes	25	Radiographic and clinical union	88.0% (22/25) healed
Brighton ⁶⁶	IV	Long-bone nonunion	22	Radiographic union	77.3% (17/22) healed
Impagliazzo ⁶⁸	IV	Long-bone nonunion	30	Radiographic union	83.3% (25/30) healed
Zamora-Navas ⁶⁷	IV	Long-bone nonunion	22	Radiographic union	72.7% (16/22) healed
Pulsed electromagnetic field					
Sharrard ⁷³	I	Tibial nonunion	45	Radiographic union	In 12 weeks, healing for 45% (9/20) in the pulsed electromagnetic field group and 12.0% (3/25) in the control group
Dhawan ⁹⁵	I	Ankle fusion	64	Time to fusion	Mean time to fusion of 12.2 weeks in the pulsed electromagnetic field group and 17.7 weeks in the control group (p = 0.003)

Kennedy ⁹⁷	I	Peri-implant fracture of the hip	37	Radiographic union	Healing of 52.6% (10/19) in the pulsed electromagnetic field group and 11.1% (2/18) in the control group
Linovitz ⁹⁴	I	Spinal fusion	201	Successful fusion	Healing at 9 months for 64% in the pulsed electromagnetic field group and 43% in the control group
Livesley ⁹⁸	I	Fresh humeral fracture	67	Radiographic union	No difference between pulsed electromagnetic field group and control group
Mammi ⁹⁹	I	Fresh tibial osteotomy	37	Radiographic union at 60 days	Healing at 60 days for 72.2% (13/18) in the pulsed electromagnetic field group and 26.3% (5/19) in the control group
Mammi ⁹³	I	Spinal fusion	35	Radiographic union at 4 months	Healing at 4 months for 80% (12/15) in the pulsed electromagnetic field group and 35% (7/20) in the control group
Mooney ⁹²	I	Spinal fusion	195	Radiographic union at 12 months	Healing at 12 months for 82.7% (81/98) in the pulsed electromagnetic field group and 64.9% (63/97) in the control group
Simonis ⁷¹	I	Tibial nonunion	34	Radiographic union at 6 months	Healing at 6 months for 88.9% (16/18) in the pulsed electromagnetic field group and 50.0% (8/16) in the control group
Traina ⁷²	I	Tibial nonunion	37	Radiographic union at 60 days	Healing at 60 days for 72.2% (13/18) in the pulsed electromagnetic field group and 26.3% (5/19) in the control group
Bassett ⁷⁶	III	Long-bone nonunion	1,078	Radiographic union	77% (834/1,078) healed
Adams ⁷⁷	IV	Scaphoid nonunion	54	Radiographic union	69% (37/54) healed
Bassett ⁷⁸	IV	Tibial nonunion	127	Radiographic union	89.8% (114/127) healed
Bassett ⁷⁵	IV	Femoral-head osteonecrosis	95	Osteonecrosis radiographic progression	Pulsed electromagnetic field treatment showed long-term reduction in osteonecrosis progression and a reduction in the need for arthroplasty
Colson ⁸⁰	IV	Long-bone nonunion	33	Radiographic healing at 12 months	93.9% (31/33) healed at 12 months
de Haas ⁸¹	IV	Tibial nonunion	56	Radiographic healing at 12 months	84% (47/56) healed at 12 months
Delima ⁸²	IV	Long-bone nonunion	30	Radiographic healing at 12 months	80.0% (24/30) healed at 12 months
Fontanesi ⁸³	IV	Long-bone nonunion	35	Radiographic union	88.6% (31/35) healed
Fontanesi ⁸⁴	IV	Long-bone	146	Radiographic union	86% (126/146) healed

		nonunion			
Freedman ⁸⁵	IV	Long-bone nonunion	13	Radiographic union	15.4% (2/13) healed
Frykman ⁹⁰	IV	Scaphoid nonunion	44	Radiographic union	79.5% (35/44) healed
Garland ⁸⁶	IV	Long-bone nonunion	90	Radiographic union at 4 years	92.2% (83/90) maintained a solid union at 4 years
Holmes ⁸⁷	IV	Delayed union of proximal fifth metatarsal fracture	9	Radiographic union	100.0% (9/9) healed
Ito ⁸⁸	IV	Delayed union of tibial fracture	30	Radiographic union	83.3% (25/30) healed
Marcer ⁸⁹	IV	Long-bone nonunion	147	Radiographic union	72.8% (107/147) healed
Meskens ⁷⁴	IV	Tibial nonunion	57	Radiographic union	75.4% (43/57) healed
Saxena ⁹⁶	IV	Ankle fusion	28	Successful fusion	85.7% (24/28) radiographically fused
LIPUS					
El-Mowafi ¹¹⁹	I	Distraction osteogenesis	20	Mean healing index	30 days/cm with LIPUS and 48 days/cm in control group; reduced time of distraction osteogenesis with LIPUS
Emami ¹⁰⁰	I	Fresh tibial fracture	32	Time to healing	128 days for LIPUS group and 114 days for placebo group; no effect of LIPUS on time to healing of fresh tibial fractures
Heckman ¹⁰¹	I	Fresh tibial fracture	67	Time to healing	Mean time to healing of 86 days in the LIPUS group and 114 days in the control group
Kristiansen ¹⁰²	I	Fresh distal radial fracture	61	Time to healing	Mean time to healing of 61 days in the LIPUS group and 98 days in the control group
Lubbert ¹⁰⁷	I	Fresh clavicular fracture	101	Time to healing, return to activity, VAS	No difference between cohorts in any measure
Mayr ¹⁰³	I	Fresh scaphoid fracture	30	Time to healing	Mean time to healing of 43.2 days in the LIPUS group and 62.0 days in the control group
Busse ¹⁰⁸	I	Tibial fracture with intramedullary nailing	501	SF-36, time to union, PCS score, function, adverse events	No difference between LIPUS and sham groups
Ricardo ¹⁰⁹	I	Scaphoid nonunion	21	Time to healing, radiographic union	All patients achieved fracture union (active and placebo groups), but compared with the placebo device (11 patients), the active device (10 patients) accelerated healing by 38 days (56 ± 3.2 days compared with 94 ± 4.8 days; p < 0.0001, analysis of variance)

Rue ¹¹⁷	I	Tibial stress fracture	43	Time to healing, return to activity	No difference in time to healing or time to return to activity between LIPUS and control cohorts
Salem ¹¹⁸	I	Tibial distraction osteogenesis	21	Mean healing index	33 days/cm with LIPUS group and 45 days/cm in control group; reduced time of distraction osteogenesis with LIPUS
Strauss ¹⁰⁴	I	Fresh Jones fracture	20	Time to union, radiographic union	At the end of treatment, there was a significant decrease in the mean time to clinical and radiographic healing in LIPUS patients; 100% (10/10) in the LIPUS cohort and 70% (7/10) in the control cohort went on to union
Urita ¹⁰⁵	I	Osteotomy site healing after forearm bone shortening	27	Time to union	The mean times to complete cortical union were 57 days in the LIPUS group and 76 days in the control group; regarding endosteal union, the mean times were 121 days in the LIPUS group and 148 days in the control group
Gebauer ¹¹⁰	IV	Long-bone nonunion	67	Radiographic union	85% (57/67) healed
Nolte ¹¹³	IV	Long-bone nonunion	29	Radiographic union	86% (25/29) healed
Mayr ¹¹¹	IV	Long-bone nonunion	100	Radiographic union	86% (86/100) healed
Rutten ¹¹²	IV	Tibial nonunion	71	Radiographic union	73% (52/71) healed
Pigozzi ¹¹⁴	IV	Pseudarthrosis	15	Radiographic union	100% (15/15) healed
Schofer ¹¹⁵	I	Delayed union of tibial fracture	101	Bone mineral density and bone gap area	Mean improvement in bone mineral density was 1.34 (90% CI, 1.14 to 1.57) times greater for LIPUS-treated subjects compared with sham (p = 0.002); a mean reduction in bone gap area also favored LIPUS treatment (p = 0.014)

*VAS = visual analog scale, and CI = confidence interval.