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The role of the monopolar electromyographic pin in myofascial pain therapy: automated twitch-obtaining intramuscular stimulation (ATOIMS^{SM}) and electrical twitch-obtaining intramuscular stimulation (ETOIMS^{SM})

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Abstract

Objective: *To show that the monopolar pin electrode has a role in the control of radiculopathy related myofascial pain and fibromyalgia using the automated twitch-obtaining intramuscular stimulation (ATOIMS^{SM}) and electrical twitch-obtaining intramuscular stimulation (ETOIMS^{SM}) methods.*

Method: *A hand-held ATOIMS device facilitated the insertion, oscillation and retraction of the monopolar pin into motor end-plate regions. The device oscillated the pin at 2 Hz for three times in two seconds. ETOIMS method employed micro-stimulation at 2 Hz for two seconds/point. Obtaining muscle twitches were the goals of both treatments. This is a retrospective study of two patients with fibromyalgia who received these treatments. Patient #1 with chronic low back > neck pain, underwent treatments which included the L2-S1 myotomes and patient #2 with chronic neck pain > low back pain, received treatments to the bilateral C2-T1 myotomes. Both received treatments also to bilateral C_3-S_1 paraspinal muscles. Treatments to both began with ETOIMS for two months and five months respectively. Following this period, they both received ATOIMS and ETOIMS to the same muscles in the same treatment session. The combined procedure sessions continued for the same treatment duration as for ETOIMS only sessions. Both patients recorded daily visual analog pain levels.*

Results: *Significant reductions in pain levels occurred with the increase in number of ETOIMS treatment sessions. More significant pain level reductions occurred with combined ATOIMS & ETOIMS treatments than with ETOIMS only treatments. The monopolar pin served both procedures well and there were no complications.*

Conclusions: *The monopolar pin has a very promising role in the management of radiculopathy related myofascial pain using the ATOIMS and ETOIMS methods.*

Key-words: Monopolar pin – Twitches – Radiculopathy – Myofascial pain – Fibromyalgia – ATOIMS – ETOIMS.

Introduction

The monopolar pin electrode's role in electromyographic (EMG) examinations is well established. This paper describes a novel use of this pin as an important therapeutic tool in the management of radiculopathy related myofascial pain and fibromyalgia. The author noted pain reduction after EMG examinations on needling tender points along muscle bands, cords or knots (5, 6). Miniature end-plate potentials (MEPPs), end-plate potentials (EPPs), fasciculations, myokymic discharges and twitches are recordable at these points. The discharges may also be in the form of grouped single muscle fiber discharges (positive, negative, or negative-positive wave forms). The elicitation of these twitch potentials, when manifested clinically as palpable, visible or strong and forceful movements are useful for pain reduction (5-10).

Gunn suggests that pain associated with myofascial pain syndrome and fibromyalgia results

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from muscle shortening associated with denervation due to spondylotic radiculopathy. The muscle fiber shortening produces a traction effect on nerves, blood vessels, tendons, bones and joints (14-16). He developed intramuscular stimulation (IMS) to treat these conditions. The method involves manual insertion and oscillation of an acupuncture pin via a plunger at tender motor points. The guiding cannula's distal end has to be supported with the non-dominant hand while the dominant hand produces "pecking" and "twirling" movements of the acupuncture pin affixed to a plunger. These movements presumably cause muscle shortening to initially intensify and then relax, resulting in pain relief. The wide-opening of the cannula's distal end does not support, splint or protect the pin as it penetrates the tissue. This allows the wiry pin (diameter approximately 0.010 inch) to bend or twist corkscrew style on encountering thickened tissue. Thus, motor end-plate zones that are deeply situated and/or covered by thickened tissue and fascia cannot be treated. Lack of inherent strength of the acupuncture pin prevents twitch elicitation, thus twitches have not been reported in IMS therapy.

Pain relieving effects with the monopolar pin electrode after EMGs prompted the author to use this pin in the treatment of myofascial and fibromyalgia pain (5-10). The stiffness of the monopolar pin due to its thicker diameter (Oxford Instruments MG 37 and MG 50 monopolar pins, with diameter of 0.016 inches) was ideal for such use. The pin permitted single-handed operation. The Teflon coating provides smooth pin penetration into the thickened tissue and prevents tissue from adhering to the oscillated pin. The conical tip of the monopolar pin unlike the bevelled tip of a hypodermic needle is less traumatic to tissues. This feature is of paramount importance since the objective is to minimize tissue trauma in chronic pain patients who need long-term treatments.

Twitches are easily elicited on performing IMS with the monopolar EMG pin (7-10). However, thousands of oscillations must occur in this therapy that includes treatment to multiple myotomes to achieve significant pain relief in chronic pain patients. The risk of repetitive stress injuries to the physician is proportional to the number of patients treated, the intensity, and diffuseness of their pain symptoms. Also, there is significant difficulty in pin penetration of the skin, a fact directly dependent on the length of the monopolar pin used and skin thickness. The physician therefore has to employ gross and fine muscular efforts to push the pin into tissues. Therefore, on locating a twitch-point, the physician finds it technically more efficient to change directions of the pin within the muscle to find adjacent excitable motor end-plate zones. This is easier than to re-penetrate the skin. This intramuscular change in direction of the pin causes significant pain to the patients, a point familiar to most electromyographers. The irregular trajectory of the manually inserted pin as it encounters tissues of differing resiliencies is also a significant source of pain during treatment.

Therefore, in order to facilitate the treatments and improve the limitations imposed by the manually operated method, the author developed an automated system for pin oscillation. This method called the automated twitch-obtaining intramuscular stimulation (ATOIMS) uses a custom-made device which automatically inserts, oscillates and retracts the pin from the muscle. The ATOIMS device allows only one trajectory. The smoothness of this trajectory reduces pain associated with the treatment since there is less tissue trauma.

However, even with automation there is difficulty with twitch elicitation since the mechanical stimulus from the oscillating pin has to be at the irritable motor end-plate zones for the twitch to occur. For twitch facilitation, micro-electrical current stimulation can be used. Teflon-coated monopolar pins have an established role in stimulation single fiber EMG (27, 31). On using this pin for electrical twitch-obtaining intramuscular stimulation (ETOIMS), there is focused delivery of electrical charge only to the motor end-plate zones. Since this type of pin is bare only at the very tip (0.3 mm^2), there is no current loss to surrounding tissues. This feature limits unnecessary electrical stimulation to tissues adjacent to the shaft of the pin. Also, with ETOIMS the twitch occurs immediately on muscle penetration. The facilitation of twitches with electrical stimulation by-passes the need to hunt for twitch points intramuscularly thus limiting treatment pain.

The following is a description of the ATOIMS device, and the role of the monopolar pin electrode in ATOIMS and ETOIMS therapy.

Materials and methods

The ATOIMS device is a metal injection system which comprises a protective tube and a pipe adapted for use with a computerized power injector system. This allows a specifically chosen pin to quickly penetrate the patient's skin and give intramuscular stimulation with greater accuracy, efficacy and less pain. The system is designed for use with monopolar EMG pins (Oxford Instruments, Old Woking, UK). Three different lengths of EMG pins (75 mm, 50 mm or 37 mm) can be used according to the depth of penetration desired. The depth and direction of an injected chosen pin is computer controlled. This avoids the risk of damage to tissue beyond the depth of pin penetration and also that which is adjacent to the pin trajectory. The movement of the pin is unidirectional and therefore minimizes tissue trauma. This ATOIMS device improves reliability of treatment and reduces repetitive muscle stresses associated with injecting the pin into the tissues. It can also maintain the oscillatory motion needed for twitch elicitation.

Detailed description of ATOIMS device

The ATOIMS device (weighs approximately two lbs) relies on the motion of the engine which is powered by a 24 volt battery. The system starts on pressing down on the foot pedal initiating the engine (#18 in Figure 2) to undergo a circular movement. The teeth on the gear wheel (Fig. #4) moves on the teeth of the straight gear (Fig. #3) connected to the pin handle (Fig. 2 #12). This motion transfers the circular movement to a linear movement. Movement of the pin handle (#12) allows a pin (#11) to move back and forth within the metal protective tube (#10) and pipe (#9) . On triggering the foot pedal, or the start button on the control box (not shown), the pipe (#9) placed at a chosen site on the patient's skin allows the pin to quickly penetrate the skin. The pin oscillating at

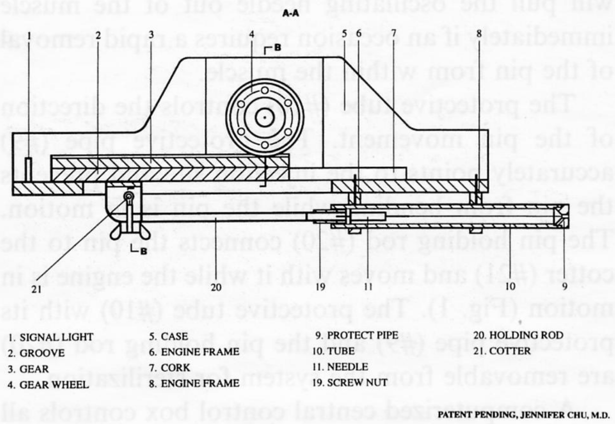

Fig. 1. – Side isometric view of the invention. This displays an automatic pin injector system featuring the assembled relationships of a power engine, a cotter which controls the speed and the position of the pin used for injection, and a pin-holding tube.

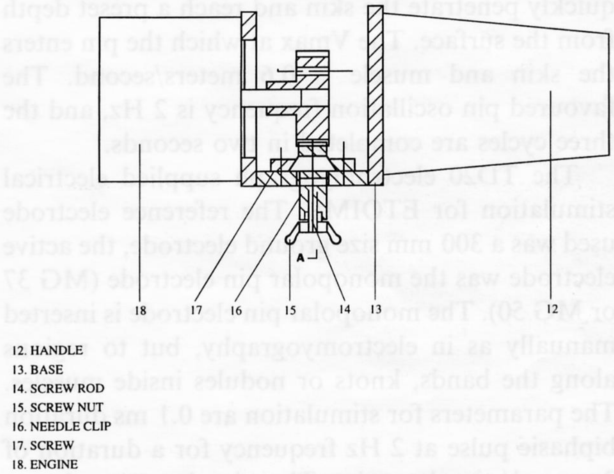

Fig. 2. – Inside, end view of the system illustrating how a battery powered engine transfers a circular motor movement to produce a linear cotter movement.

2 Hz stays in the muscle for two seconds. When the required pin depth is reached, the pin will oscillate 20 mm backwards and forwards three times. The pin movements then stop and the pin is retracted automatically back into the protective tube (#10). The movements of the pin can also be stopped immediately by pressing a red stop button on the central control box. The hand-held injector system can also be immediately withdrawn manually. This

will pull the oscillating needle out of the muscle immediately if an occasion requires a rapid removal of the pin from within the muscle.

The protective tube (#10) controls the direction of the pin movement. The protective pipe (#9) accurately points to the injection site and prevents the pin from bending while the pin is in motion. The pin holding rod (#20) connects the pin to the cotter (#21) and moves with it while the engine is in motion (Fig. 1). The protective tube (#10) with its protective pipe (#9) and the pin holding rod (#20) are removable from the system for sterilization.

A computerized central control box controls all engine movements. Pre-set software in the box has an adjustable stop position for different lengths of pins and allows each pin to stay within the protective tube (#10). Turning on the automatic injector following positioning of the protective pipe (#9) on the skin surface allows the box to send signals to the engine. These signals allow the pin to quickly penetrate the skin and reach a preset depth from the surface. The Vmax at which the pin enters the skin and muscle is 0.6 meters/second. The favoured pin oscillation frequency is 2 Hz, and the three cycles are completed in two seconds.

The TD20 electromyograph supplied electrical stimulation for ETOIMS. The reference electrode used was a 300 mm size ground electrode, the active electrode was the monopolar pin electrode (MG 37 or MG 50). The monopolar pin electrode is inserted manually as in electromyography, but to regions along the bands, knots or nodules inside muscles. The parameters for stimulation are 0.1 ms duration biphasic pulse at 2 Hz frequency for a duration of 2 second/stimulus point. The stimulus strength was 1-5 volts. Both ATOIMS and ETOIMS methods received approval for clinical treatment purposes also at the author's institution.

Both patients had EMG studies performed on them prior to the treatments. Patient #1 had EMG studies of the lower extremities and lumbosacral paraspinal muscles and patient #2 had EMG studies of the upper extremities and cervical paraspinal muscles. Semi-quantitative methods were used as previously described (5, 6). Increased in percentage of normal duration, normal amplitude polyphasic MUAPs greater than 30% in a myotomal pattern indicated presence of ongoing nerve root irritation. Increased incidence (> 10%) of long duration MUAPs indicated presence of chronic stable re-innervation changes.

Both patients who have fibromyalgia according to the criteria established by the American College of Rheumatology (34), signed informed consent forms for the treatments. Patients #1 and #2 received treatments first with the manually performed ETOIMS for two and five months respectively. They then received ATOIMS to the muscles followed by ETOIMS to the same muscles in the same treatment session. The combined treatments continued for a similar duration as for isolated ETOIMS sessions. Both patients paid fee for service.

Patient #1 with low back pain more than neck pain (Table 1), the treatments included the following bilateral muscles: rectus femoris (L3), adductor longus (L3), vastus lateralis (L4), vastus medialis (L4), gluteus medius (L5), tensor fascia lata (L5), semitendinosus (S1), gluteus maximus (S1), adductor magnus (S1), trapezius (C4) and the bilateral paraspinal muscles from C3-S1.

Patient #2 with neck pain more than low back pain (see Table 1) received treatments to the following muscles bilaterally: sternocleidomastoid (C2), levator scapulae (C3), trapezius (C4), rhomboid major (C5), infraspinatus (C5), deltoid (C6), teres major (C6), brachioradialis (C6), triceps (C7), latissimus dorsi (C7), the first dorsal interosseous (C8-T1) and gluteus maximus (S1). The paraspinal muscles received treatment from the bilateral C3-S1 levels with the ATOIMS device. The C2-C5 myotomal levels were not treated with ATOIMS to avoid damage to internal organs. All muscles listed received ETOIMS therapy.

The goals of the ATOIMS treatments are to find strong twitches that will move large areas of the muscle. These twitches may move the joint over which the treated muscle crosses. The goals of the ETOIMS treatments are to produce twitches that are strong enough to move the joint in the direction of action of the treated muscle. At least 5-6 muscle stimulation points had to produce these twitches according to the treatment goals set for both ATOIMS and ETOIMS. The patients' treatment positions included supine, prone and alternate side-lying positions to get the stimulus into the most excitable motor end-plate zones. The ETOIMS treatments alone last one hour and the combined ATOIMS & ETOIMS treatments typically last two hours. Outcome effects of the treatments include observations of the daily pain levels scored on the visual analogue scale (VAS). On this scale, zero denoted no pain and ten denoted the worst possible pain.

Statistical analysis

A Chi square testing and logistic regression testing determined significance in differences between the results obtained. Pearson product moment correlation testing allowed correlation analysis. Significance was set at ($p \leqslant 0.01$). The software used was Statistica (Statsoft Inc., Tulsa, OK).

Results

Table 1: Shows the demographics of the two fibromyalgic patients treated. Patient #1 showed EMG evidence of multi-level lumbosacral radiculopathies and patient #2 showed evidence of multi-level cervical radiculopathies.

Table 2: There was a trend for lower pain levels with ETOIMS treatments as compared to that before the treatments. No statistical comparison could be made since the pre-treatment pain levels were an expression of the average pain level as reported by the patient. Significant negative correlations observed between the average pain levels and the number of ETOIMS treatments received ($p < 0.01$).

Table 3: Significant reductions of pain levels occurred with ATOIMS & ETOIMS combined treatments than that achieved with ETOIMS treatments only ($p < 0.01$). Significant negative correlations noted between the average pain levels with the number of treatment types used such as ETOIMS alone or ETOIMS combined with ATOIMS ($p < 0.01$).

Table 1. – *Characteristics of patients treated*

Patient (no/sex/age in years)	Symptom	Cause	Pain duration (months)	Tender points (no)	EMG (abnormal roots)	MRI
1/male/28	low back > neck pain	weight lifting	24	16	R > L L3-S1, esp. S1	spinal stenosis L5-S1
2/female/30	neck > low back pain	auto-accident	72	15	R > L C4-C8 esp. C4 and C7	normal

Table 2. – *Pain levels correlated with number of ETOIMS treatments*

Patient number (no)	VAS Pain level before ETOIMS (no)	ETOIMS treatments (no)	Pain level with ETOIMS (no)	Pain level vs number of ETOIMS (no)
1	9	8	7.1 ± 1.8	$R = -0.7$
2	8	19	6.5 ± 0.5	$R = -0.6$

Table 3. – *Pain levels correlated with type of treatments: ETOIMS alone or combined ATOIMS & ETOIMS treatments*

Patient number (no)	VAS Pain level before A & ETOIMS (no)	A & ETOIMS treatments (no)	VAS Pain level with A & ETOIMS (no)	VAS Pain level vs ETOIMS vs A & ETOIMS (no)
1	7.1 ± 1.8	11	5.2 ± 1.3*	$R = -0.6$
2	6.5 ± 0.5	21	5.8 ± 0.5*	$R = -0.5$

Difference in pain levels before and after A & ETOIMS treatments: * $p < 0.01$.

Discussion

The use of the monopolar pin was essential in eliciting twitches with ATOIMS and ETOIMS methods. The fact that isolated ETOIMS therapy was able to effectively reduce pain underscores the importance of twitches. The therapeutic effects of the twitches have not been realized until recently (7-10). Of importance is that the twitch points (motor end-plate zones) are essentially the same points as those used in body meridian acupuncture (22, 23), IMS (14-16) and trigger point injections (26, 29, 30). However, the therapeutic effect of the twitches remain unrecognized in these therapies for the following reasons. The lack of inherent strength of the pin used in acupuncture and IMS prevents significant mechanical excitation to occur at the motor end-plate zones. The practice of acupuncture is limited to points on theoretical energy meridians. Therefore, it is only by coincidence that stimulation of the motor end-plate zones occur in acupuncture. In IMS, although the stimulus is intended for the motor points, there is inadequate stimulation of these points. This is related to the lack of strength of the pin compounded by the presence of a stainless steel shaft which sticks to the tissues. This causes difficulty in manoeuvring this pin intramuscularly producing difficulty in penetration into the region of the motor end-plate zones. These methods are self-limiting and cannot be effectively used on patients with diffuse widespread pain as illustrated in this study.

The hypodermic needle used in trigger point injections is firm and strong enough to elicit twitches. Although the therapeutic effect of the twitch remains unnoticed, the twitch does have a role in the precise identification of trigger points (19, 20). But the medications injected such as local anaesthetics counteract the twitch elicitation. This is because spinal pathways are involved in the twitch response (21). The potential traumatic effects of the bevelled tip of the larger sized hypodermic needle and the iatrogenic effects of injected medications limit the role of trigger point injections in fibromyalgia.

The effects of percutaneous electrical nerve stimulation (PENS) is similar to ETOIMS. In PENS, the stainless steel shaft of acupuncture pins conduct unknown quantities of electrical current to tissues for a prolonged time for eg. 30 minutes (13). Stimulation of the larger muscle afferents will induce pain relief (24). However, it may be potentially harmful to perform prolonged electrical stimulation to tissues beside the shaft of the pin. If the effect is to induce neuromuscular fatigue, a very brief current of 2-5 seconds is sufficient (see below for explanation). The advantage of ETOIMS is that after 2 seconds, the pin is completely withdrawn. Therefore, even with a repeat procedure through the same skin insertion site, the pin is likely to take a slightly different route through the tissues. This is due to the movement of tissues caused by the twitches. The pin will therefore deliver the next series of stimuli to a new site. The maximum charge delivered to the tissues at each site will be 0.4 microcoulombs (personal communication with Oxford Instruments). ETOIMS thus has an advantage in that it is safe to apply to many points in various myotomes in a treatment session. Regular and repeated treatments are also possible.

ATOIMS and ETOIMS methods use the force, frequency and the number of twitches obtained at a treatment point to produce intramuscular exercise. The exercise effects increase circulation to the area treated (2, 33) and reduce thixotropy (stiffness) of muscle fibers (12, 17, 18). All these factors are important in the reduction of pain due to radiculopathy related muscle shortening in myofascial pain syndrome and fibromyalgia. By using the force of these twitches effective intramuscular exercise occurs at motor points deep within the muscle. These points/areas are not reachable by physical therapy modalities such as stretching, ultrasound, surface electrical stimulation or PENS.

The ATOIMS method lightened the burden of the treatment for both the patient and physician. The smooth trajectory of the oscillating pin reduces the treatment pain and minimizes tissue trauma. It also prevents injury to the physician and avoids repetitive and resistive motion activities of the upper limb. Many areas can be treated more effectively than can be done manually. However, ATOIMS is technically difficult to perform since the mechanical stimulus from the oscillating pin has to be at the hyper-excitable motor end-plate zones for clinical twitching to occur. Due to twitch difficulties associated with ATOIMS, ETOIMS given with ATOIMS had more beneficial effects for pain reduction. With ETOIMS, precise localization of the motor end-plate zones is not essential due to the presence of an effective electrical field. The fact that the pain reduction was more pronounced with the ATOIMS & ETOIMS combined method than ETOIMS in isolation, suggests that these treatments are complementary to each other. Also, manual delivery of ETOIMS is self-limiting and therefore not as effective as ATOIMS & ETOIMS combination.

The ATOIMS & ETOIMS treatments take advantage of the pathophysiological and anatomical basis of denervation supersensitivity. Denervation supersensitivity occurs in skeletal muscle from the development of multiple end plates which allow the muscle fibers to undergo slow depolarization from circulating acetylcholine (1, 4). This leads to irreversible electromechanical coupling and resultant shortening of muscle fibers with contracture. Reversible muscle shortening may occur in functional denervation related to focal demyelination and neuropraxia (10). Distributions of muscle fibers belonging to one motor unit occur over 100 fascicles in a muscle (3). Thus partial denervation from spondylotic radiculopathies with resultant muscle fiber shortening will occur in multifocal areas of the many component muscles of the many affected myotomes. Spinal nerve roots are the most susceptible of all peripheral nerves to trauma due to lack of abundant perineurial tissue (28). Thus, progressive spondylotic attrition of spinal nerve roots especially in the presence of acute or repetitive trauma, maintain the patients in a state of perpetual pain and disability.

Therefore, ATOIMS and/or ETOIMS treatments designed to fatigue motor end-plate zones with tenuous safety factors due to functional denervation and/or re-innervation must involve many treatment points/muscle in multiple bilateral myotomes. With correct pin placement, the twitches are evoked immediately upon muscle penetration. The first in a series of twitches commonly maybe sustained as in a tetanic contraction or forceful enough to move the joint in the direction of action of the treated muscle. Not uncommonly, a single stimulus evokes multiple simultaneous twitches causing the muscle to flutter. These twitch characteristics complement the EMG findings of a neurogenic component with re-excitation from presence of ectopic activity (32). The abnormal excitability may be related to presence of demyelinated or regenerating nerve endings (35).

Both the ATOIMS and/or ETOIMS method utilizes a stimulus frequency of 2 Hz for two seconds. Neurophysiologically, using a repetitive stimulus rate of 2 Hz normally results in the sequential delivery of less and less acetylcholine (Ach) vesicles with each stimulus until the delivery of 8-10 stimuli. At this time mobilization of storage Ach vesicles keep pace with exocytosis (25). Also, the rate of 2 Hz has too long an interstimulus interval to leave residual calcium in the nerve terminal that can potentially cause facilitation of Ach release. The stimulus rate of 2 Hz results in immediate depression of Ach quanta release. This leads to normal physiological reduction of the safety factor at all neuromuscular junctions. The neuromuscular junctions with tenuous safety factors undergo neuromuscular transmission block when the end-plate potential drops below threshold. This usually occurs within the first three to five stimuli. It is typical in repetitive stimulation studies of neuromuscular transmission disorders to compare the first with the fourth evoked response (11). Thus, the author limits the stimulus duration of 2 Hz stimulation with both ATOIMS and ETOIMS at each treatment point to two seconds which allows four impulses. Single fiber electromyography uses the same micro-electrical stimulus parameters to excite and fatigue immature end-plates and nerve terminals in nerve related disorders (27, 31). Both patients have ongoing and chronic multi-level radiculopathies which responded to ATOIMS and ETOIMS therapies. The basis of pain relief from the treatments may relate to the fatigue at tenuous neuromuscular junctions. This would enhance relaxation of the shortened muscle fibers resulting from functional denervation related to neuropraxia (10). These therapies will be less successful in alleviating pain associated with axonal degeneration that leads to irreversible muscle fibrosis and contracture.

The author has the advantage of using the monopolar pin electrode for EMG purposes for 23 years and has not any breakage problems with this pin. In addition, this same electrode performed excellently in its use in manual TOIMS for the past four years (7, 9) and continues to perform well in ATOIMS & ETOIMS treatments. When the pin strikes bone, a knocking sound occurs but there is no undue pain to the patients. A burr formation at the tip is extremely uncommon with this pin. With such an occurrence, an unevenness can be felt in the pin's trajectory and the pin is immediately discarded. There are no complications with ATOIMS & ETOIMS except for transient skin bruises. Pain during and after treatment if bothersome to those with significant underlying pain can be adequately controlled using oral analgesics and/or muscle relaxants. The contra-indications are similar to EMG.

This is the first description of the novel use of the monopolar pin electrode in this innovative method of myofascial and fibromyalgia pain control. The ETOIMS method is labour intensive presently since it is manually performed. The ATOIMS method is approved only for custom use and the prototype device is considerably heavy. These methods are routinely used to treat patients but further refinement is essential to make the methods more user friendly. The ultimate goal is to scientifically establish the effectiveness of myofascial pain control using ATOIMS and/or ETOIMS methods.

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