Swiss International College of Osteopathy

Thermographic Skin Measurement and Osteopathic Palpation of Tibial Intraosseous Strains in Adults - a comparative Pilot Study

by

Edward Muntinga

Thesis presented to the International Jury
in Hertenstein, Switzerland

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I would like to express my gratitude to my wife Kathia and my two children Sophie and Noah, who bared with me over the last seven years of my osteopathic studies and of writing this thesis. It was especially my wife who always supported me and gave me encouragement which allowed me to invest so much time in my passion named osteopathy.

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Also my biggest thanks are to all teachers of SICO who taught me the art of Osteopathy - as Philippe Druelle DO tends to say during courses "This is a big secret!". Yes, it is a big secret, taught from Osteopath to Osteopath, it is shared knowledge within our professional community.

Last but not least, many thanks to Robert Rousse DO who helped me give structure to my work with intraosseous strains. Robert Rousse DO‘s "Functional Emergency Technique" methodology was *my* key to really understand what my hands were actually doing while working with bones. His methodology gave me advanced effectiveness and speed to working with bones.

Thank you.

THESIS ADVISOR

Julie Brown, D.O.M.P. (Ca)

HYPOTHESES

Intraosseous strains (IOS) of the tibia identified by manual osteopathic palpation can be detected with thermal imaging by observing an area of altered average skin temperature of the anterior tibial surface.

1. The **mean average skin temperature (MAST)** of the intraosseous-affected side is lower than
   a) the **MAST** of the contralateral (healthy) side of the case (intraosseous) group.
   b) the **MAST** (baseline temperature) of the control group.
2. The **MAST difference** between the intraosseous-affected side and the **MAST difference** of the contralateral (healthy) side in the case group will be significantly higher than **MAST difference** between left and the right side within the control group.
3. There is a *negative* significant correlation between **rigidity (A/P Spring)** of the intraosseous-affected tibia and its average skin temperature.
4. There is a *positive* significant correlation between the **expression of vitality** of the of the intraosseous-affected tibia and its average skin temperature.
5. There is *no* significant correlation between the **accident/injury/operation (AIO)** age of an IOS and the average skin temperature of the intraosseous-affected tibia.

In order to make it easier for the reader to understand the hypotheses stated above, a schematic figure of the taken thermal images and a table with formula-like descriptions of the hypotheses are added below:

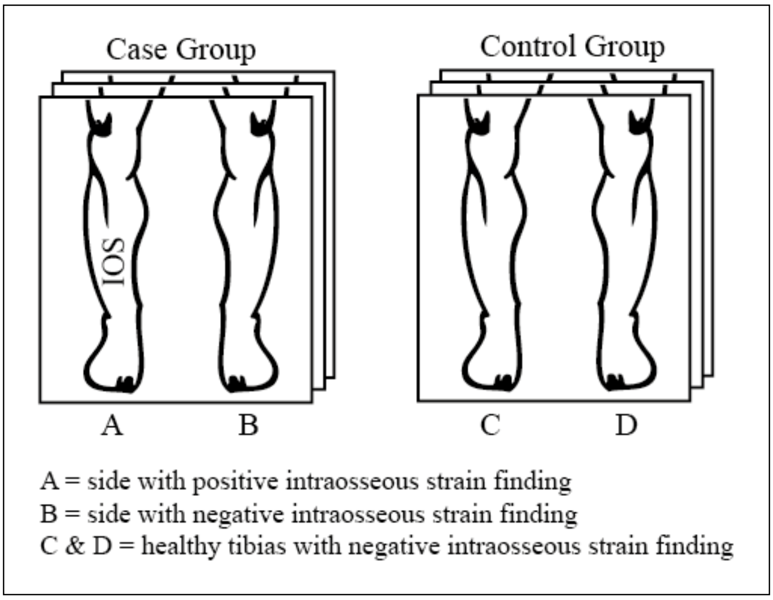

Figure. 1: Thermal images schematic

Table: 1. FORMULA-LIKE DESCRIPTION OF THE HYPOTHESES

Hypothesis 1 a) and b)	**Hypothesis 2**
a) MAST (A) < MAST (B) b) MAST (A) < MAST (C & D)	MAST (B:A) > MAST (C:D)
Hypothesis 3	**Hypothesis 4**
Rigidity (A/P Spring) (A) correlates **negatively** with its average skin temperature	Vitality (A) correlates **positively** with its average skin temperature
Hypothesis 5	MAST = mean average skin temperature
Accident/injury/operation age (A) does **not** correlate with its average skin temperature	

ABSTRACT

The purpose of this study was to assess thermography as a viable assessment tool to identify IOS in the tibial bone, and to establish a correlation between thermography and osteopathic palpation.

This quantitative, single-blinded observational study wanted to ascertain if it is possible to detect IOS of the tibial bone in adults by comparing thermal patterns of the overlying skin of the anterior tibia. Furthermore, it wanted to show statistically significant relations between specific osteopathic manual palpation parameters, age of the IOS and thermal information. This study used a sample size of of N=86 (20 affected tibias in the case group (leg A), 20 unaffected tibias in the case group (leg B), and 46 tibias in the control group (C&D)) which gave statistically significant data through cross-tables and other statistical calculations. Strict inclusion and exclusion parameters in both sample groups (case and control group) were defined to ensure valid thermal image material.

Firstly, all subjects would fill out a questionnaire which supplies information on the individual, the symptoms at present time and the history of any traumatic incidents with possible date ranges. Secondly, a standardized thermal image of the anterior surface of the tibias was taken in compliance with international standards in medical thermography. Thirdly, the blinded examiner, the author of this thesis, performed a predefined and standardized osteopathic palpation procedure to locate and classify any existing intraosseous strains. Palpatory parameters such as rigidity of the bone and expression of local vitality were assessed and categorized. Lastly, the given data was processed and analyzed by a statistician.

Hypotheses 1b, 2 and 3 were statistically confirmed and they showed that the more rigid an IOS is, the colder its overlying skin temperature. Furthermore, an IOS affected region is generally colder than an IOS-unaffected region.

These results indicate that

1. thermal patterns correlate with osteopathic palpation;
2. it is possible to localize IOS with thermography;
3. an IOS negatively affects its overlying skin temperature.

Hypothesis 1a, 4 and 5 were rejected, the given data could not confirm any significant correlation between vitality and age of an IOS in relation to its rigidity.

KEYWORDS

intraosseous, strain, lesion, thermography, thermal, skin temperature, rigidity, vitality, age, bone, osteopathic palpation

RÉSUMÉ - FRENCH ABSTRACT

Le but de cette étude était d'évaluer la thermographie comme un instrument d'évaluation applicable pour identifier des lésions intraosseuses (English: "intraosseous strains", abbreviated "IOS") dans l'os du tibia, et d'établir une corrélation entre la thermographie et la palpation ostéopathique.

Cette étude quantitative, simple blindé, observationnelle, a voulu vérifier s'il est possible de détecter des IOS de l'os du tibia chez les adultes en comparant les modèles thermiques de la peau sous-jacente du tibia antérieur. En outre, on voulait montrer les relations statistiquement significatives entre les paramètres de la palpation manuelle spécifique ostéopathique, l'âge de la IOS et de l'information thermique. Cette étude a utilisé un échantillon de = 86 de N (20 tibias touchés dans le groupe des cas (jambes A), 23 tibias non affectés dans le groupe des cas (jambes B, et 46 dans le groupe témoin (C & D)) qui a donné des résultats statistiquement importants à travers de tableaux croisés et autres calculs statistiques. Des paramètres strictes d'inclusion et d'exclusion dans les deux groupes de prélèvement (le group de cas et de témoin) ont été définis afin d'assurer des images thermiques valides.

Tout d'abord, tous les sujets auraient remplit un questionnaire donnant des renseignements sur l'individu, les symptômes au moment présent et l'histoire de tous les incidents traumatiques avec des plages de dates possibles. Deuxièmement, une image thermique standardisée de la face antérieure du tibia a été prise conformément au standard international de la thermographie medicale. avec les normes internationales dans le domaine médical thermographie. Troisièmement, l'examinateur en blindé, l'auteur de cette thèse, a effectué une procedure de palpation osteopathique prédéfinie et standardisée pour localiser et classifier les lésions existantes intraosseuses. Des paramètres palpatoires, tels que la rigidité de l'os et l'expression de la vitalité locale, ont été évalués et classés. Finalement, les données fournies ont été traitées et analysées par un statisticien.

Les hypothèses 1b, 2 et 3 ont été statistiquement confirmées et ils ont montré que le plus rigide une IOS est, le plus basse la température de la peau sus-jacente est. En outre, une région touchée par und IOS est généralement plus froide qu'une région qui n'est pas affecté par une IOS.

Ces résultats indiquent que

- les modèles thermiques sont en corrélation avec la palpation ostéopathique;
- il est possible de localiser l'IOS avec la thermographie;
- une IOS affecte négativement la température de la peau sus-jacente.

Hypothèse 1a, 4 et 5 ont été rejetés, les données fournies ne pouvait pas confirmer une corrélation significative entre la vitalité et l'âge d'une IOS par rapport à sa rigidité.

MOTS-CLÉS

intraosseuse, tension, lésion, thermographie, thermique, température de la peau, rigidité, vitalité, âge, os, palpation ostéopathique

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LIST OF ACRONYMS

- **MAST = Mean Average Skin Temperature**. MAST is the mean temperature of a predefined skin area anterior to the tibial bone.
- **IOS = Intraosseous Strain**. Generally in osteopathic literature the term intraosseous *lesion* is used.
- **AIO = Accidents / Injuries / Operations**. This term is used in the questionnaire given to all examination subjects.

1 CHAPTER ONE: INTRODUCTION

1 CHAPTER ONE: INTRODUCTION

The primary aim of this thesis is to assess a quantitative method - thermography - for detecting intraosseous strains[1] (IOS) of the tibia in adults and furthermore to indicate their existence. This knowledge will prepare the path for further research on the physiological nature of IOS and on the effectiveness of testing and treatment methodologies. Thermography is being tested here for the first time in association with IOS according to the author‘s current research knowledge.

Already during osteopathic training the author assessed and treated IOS. The authors' clinical experience is that successful treatment of IOS can literally "unlock" rigid areas which have been caused by preceding trauma, no matter how far back the incident lies. During the years it appeared to the author that many other therapists, mainly from other proffessions like Physiotherapists, Medical Doctors or Chiropractors, could firstly not intellectually grasp the concept of an IOS and secondly had a hard time perceiving that "rigidity" in the bone. The authors personal experience during osteopathic training was (and still is) that if one can intellectually understand the concept of an IOS, the pathways are open to manually perceive an IOS.

In 2008, Robert Rousse DO gave a course in "Functional Emergency Techniques I" (2002) in the Swiss International College of Osteopathy - this course clearly increased the authors' methodological structure and effectiveness of finding and treating IOS. From then on, treating IOS has become a central focus in the author‘s clinical work.

The author found little written information on testing, treatment, physiological nature and classification of IOS in adults (Brown, 2008; Chauffour & Prat, 2002; Heller, 2005, 2011).

[1] author’s note: in SICO/CEO/CCO, they call it an "intraosseous lesion", Brown DOMP (2008) recommends naming it "intraosseous strain" due to high potential of misunderstanding in the medical world.

Chauffour DO & Prat DO (2002) teach methods for testing and treating IOS in their courses. Heller DC (2011), a certified Chiropractor and student of Chauffour DO & Prat DO, wrote some articles about their testing and treating methods. Since the author did not take part in any course given by Chauffour DO & Prat DO, an individual testing protocol will be used for this study.

In 2011, the author obeserved thermal readings of five subjects with an IOS in one of their tibia. Already there the data showed clear indications that a tibial skin surface tends to have altered skin temperature than the opposite side. This additionally motivated the author to start his research.

Some theses known to the author were written about the subject "intraosseous strains", one qualitative by Brown DOMP (2008) and three quantitative by François Thibault DO (2009), Jean-Sébastien Arcand DO (2011) and Jayson Horton DO (2011).

Brown DOMP (2008) performed a qualitative research on the term "intraosseous lesion" which is being used in the Canadian College of Osteopathy and also in the Swiss International College of Osteopathy and stated the following definition:

> An intraosseous lesion/strain is an osteopathic term that describes the altered state of osseous matrix in a part of a bone due to a sudden or chronic force, expressed by increased rigidity, altered force transmission, and reduced vitality. (Brown, 2008)

Brown DOMP (2008) suggested that one should use the term "intraosseous strain" and not "intraosseous lesion", in order to prevent confusion within the medical world. The term lesion usually describes a structural damage within tissue due to a pathological process. Details about this are described in Chapter 2.

Thibault DO (2009) wrote a thesis about treatment of intraosseous lesions *after* a fracture of the radius bone and its results measured with quantitative ultrasonography. Twenty-eight subjects aged between 20 and 85 years were randomly divided into an experimental and a control group. After a standardization general osteopathic treatment, the subjects in the experimental group received two osteopathic treatments with an intraosseous approach and the control group two false treatments. After the treatments, significant improvement in range of motion for flexion, extension, cubital deviation, pronation, supination and grip strength for the experimental group was observed. Unfortunately, no significant difference was found for quantitative ultrasonography measurements.

This thesis covered the whole aspect of intraosseous lesions beyond the fracture threshold of bones, thus not of IOS of non-fractured bones. Furthermore, quantitative ultrasonography was not able to measure any significant difference between the group being treated osteopathically and the control group.

Horton DO (2011) also wrote a thesis about treatment of consolidated traumatic fractures measured by quantitative ultrasound (QUS) before and after application of a specific regime of osteopathic intraosseous techniques (N=144). The study protocol consisted of a specific regime of five osteopathic techniques applied to the radial bone with a consolidated traumatic fracture (experimental group, n=72), and the contra-lateral radial bone (control group, n=72) received no treatment or intervention. Two QUS scans, measuring the speed of sound expressed in meters per second, were measured in the experimental and control groups immediately before, after, and 10-14 days after the first osteopathic treatment.

No significant change ($p = 0.165$) in bone quality was found between pre treatment, post treatment and follow up QUS scans for either group but other significant discoveries were made. Within those subjects with a pre treatment osteopathic intraosseous dysfunction, the data analyses revealed that a significant increase in Speed of Sound (SOS) occurred between pre and post treatment measures but not the follow up, in both the experimental and control group (p= 0.050). Horton DO (2011) suggested that in order for bone quality to improve from specific osteopathic intraosseous treatment, there must be a perceivable osteopathic intraosseous dysfunction present, pre treatment.

In a thesis written by Arcand DO (2011), the author investigated on 29 subjects the effect of osteopathic treatment of "non-fractured intraosseous lesions" in relation to unipodal postural stability and pain with a Wii™ Balance Board. No conclusive information on the physiological nature of IOS and no quantitative indication for actual existence of IOS were found.

In order to gain valid palpatory and thermal data, the author chose the tibial bone for this research. The tibia is relatively easy to palpate, its anterior surface is covered with little soft tissue (skin, fascia and musculus tibialis anterior) and the tibia is often affected in mechanical traumata of the legs (Heller, 2005). All the above mentioned advantages are expected to produce useful quantitative results within this study.

In the medical world, thermography is widely used for identifying and interpreting pathological conditions such as poor blood flow (Raynaud‘s Syndrome), breast cancer, osseous tumors and many more. This research project is the first attempt to compare skin temperature and the phenomenon of IOS.

As a result to the above mentioned statements, this thesis will try to fulfill the following purpose:

The purpose of this study is to assess thermography as a viable assessment tool to identify IOS in the tibial bone, and to establish a correlation between thermography and osteopathic palpation.

This thesis is designed as a quantitative single-blinded observational study.

2 CHAPTER TWO: REVIEW OF LITERATURE AND OSTEOPATHIC JUSTIFICATION

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2.1 INTRODUCTION

Stone DO (2002) mentions that Osteopaths around the world find, test and treat IOS. She also mentions that with a bit of practice, one can palpate the "elastic recoil properties" of bones. With IOS, the increase in density alters the whole dynamic of the bone, affecting its natural spring and resilience and ultimately contributes to articular stress and soft tissue pain (Stone, 2002).

As far as the authors' knowledge goes, all literature on IOS is based on empirical experience and not on quantitative research. It seems that no one has proven its existence before. Within osteopathic training in the Swiss International College of Osteopathy, the author received methodologies in assessing and treating IOS.

This Chapter describes the current state of knowledge about IOS in the medical and osteopathic world. Unfortunately, little written information is published regarding this phenomenon, especially in the medical literature. In osteopathic literature, the term *intraosseous* is mainly used in pediatric literature. The authors (Carreiro, 2009; Frymann, 1998; Liem, Schleupen, Altmeyer, & Zweedijk, 2010; Sergueef, 2007) talk about testing and treating immature bones, especially their embryological segments, their ossification centers and their intraosseous relations. Hardly anyone talks about IOS in matured bones.

This thesis used a thermal imaging camera to compare skin temperature of the anterior tibia. Thermal imaging cameras detect radiation in the infrared range of the electromagnetic spectrum (roughly 9,000–14,000 nanometers or 9–14 μm) and produce images of that radiation pattern, called *thermograms* (Diadikes & Bronzino, 2008).

In this Chapter, the author will demonstrate that thermography is a well-known tool in the medical world. It is being used for early detection of various pathologies, even for pathologies which take place underneath the human skin as physiological processes within the bone tissue itself. The literature research will show that thermography is an adequate quantitative measurement tool for indicating the existence of IOS.

In order to find out what "abnormal" skin temperature of the lower extremity is and which processes control shell temperature[2] of the human body, the author tried to find literature about thermoregulation and will show that there is no preexisting data for baseline temperature of the anterior skin surface of the tibia.

Within this thesis, osteopathic manual palpation was used to gain data on IOS. Positive findings (or negative), amount of spring of the bone and its vitality was manually measured by the author. As far as the author is aware of up to today, osteopathic manual palpation of spring and vitality of the bone are the only existing tools to find and classify IOS. This palpative information together with thermal data of each tibia were used for statistical analysis to support or decline the hypotheses stated.

In summary, subchapters with osteopathic justifications such as A.T. Still DO and his relation to bones, fluid flow within bone tissue, mechanotransduction, anatomy and physiology of the tibia, segmental reflexology, embryological development, energetic anatomy and energetic aspects of mechanical trauma are added. These subchapters try to give a basic knowledge of factors which might be part of the nature of IOS.

2.2 Current Knowledge of Intraosseous Strains

As stated in the introduction chapter, an IOS is an osteopathic term that describes the altered state of osseous matrix in a part of a bone - as Brown DOMP (2008) states - "due to a

[2] shell temperature: superficial skin temperature, not the same as core temperature which exists within the body

sudden force or repeated mechanical stress, expressed by increased rigidity, altered force transmission, and reduced vitality". Brown DOMP (2008) preferred to use the term "strain" instead of "lesion" because its use within the medical profession usually indicates cancerous processes and is generally connected with pathological processes.

In order to clarify this issue, a search in PubMed (Database, 2011) for terms associated to IOS within the research titles was performed and following results were delivered:

Table: 2. SUMMARY OF PUBMED RESEARCH FOR SPECIFIC TERMS

Term	Result
Lesion(s)	89055
Strain(s)	47973
Intraosseous	2224
Bone fracture(s)	1007
Bone lesion(s)	898
Bone strain(s)	97
Bone bruise(s)	23
Intraosseous lesion(s)	4
Intraosseous strain(s)	none

The given results clearly show that the osteopathic term *intraosseous strain/lesion* in this specific combination is hardly used in medical literature. First of all, the term *intraosseous strain(s)* did not return any results at all. The term *intraosseous lesion(s)* is mainly used to describe cystic changes (Sanerkin, Mott, & Roylance, 1983) and cancerous processes (Park, Nam, Park, & Kim, 2008; Sikes, Ghali, & Troulis, 2000) within bone tissue. The term *bone bruise(s)* mainly describes a fractured state of bone tissue (Newberg & Wetzner, 1994), *bone strain(s)* mainly describes bone strain measurements (mechanical loading) (Yang, Bruggemann, & Rittweger, 2011) and *bone lesion(s)* mainly describes cancerous processes within bone tissue (Brousse, Piette, Ackermann, Kahn, & Boisaubert, 2011; Nichols & Dixon, 2011).

The term *intraosseous* in medical literature is mainly used as a description of an access method into bone tissue (Heyder-Musolf, Giest, & Strauss, 2011; Reiche, 2003; Schalk et al., 2011) or in relation with cancerous processes (Budhdeo, Ibrahim, Hofer, & Gillies, 2011; Cil, Simsek, & Yildiz, 2011) within bone tissue. The term *strain(s)* gave various results, mainly describing biomolecular processes and microorganisms as viruses et cetera. The term *lesion(s)* brought up most results and is generally being used as a specification for any structural change within any tissue.

Julie Brown DOMP (2008) qualitatively researched the concept IOS using methods like documentary-historical method (literature review, material culture), survey method (survey, structured interview) and field method (key informant, unstructured interview). Data sources included surveys of international osteopaths, students, teachers, assistants, and graduates, course notes, thesis documents of the CCO and of course international osteopathic literature. This extensive research (sample size of n= 350) resulted in a clear definition of the term IOS which is the basis for this thesis.

Within methodology teachings of the Swiss International College of Osteopathy, as developed by Philippe Druelle DO, an IOS is a "non-physiological lesion without respect of axis". This means that an IOS is of primary importance in osteopathic treatment because it markedly impairs global, regional and local motility and vitality (Laflamme, 2006) by not respecting its physiological position and/or axes.

Philippe Druelle DO, an experienced osteopath and teacher, defines an osteopathic intraosseous lesion as

> "A change inside of living bony tissue, expressed by change in mechanical resistance (spring); change in vascularization; change in fluid flow; change in its surrounding/perfusing electro-magnetic field; and a change in local Primary Respiratory Motion." (Druelle, 2012)

This zone - an intraosseous lesion - often induces a decrease of bioenergy locally and of its neighboring bones and also decreases expression of vitality within the tissue affected by it (Druelle, 2012). He furthermore claims that traditional soft tissue and osteoarticular techniques usually do not affect intraosseous lesions.

Additionally, as described by Philippe Druelle (2012), the human life field is not able to perfuse or "pass" through an intraosseous lesion. Druelle (2012) also mentioned his clinical observation that usually a young intraosseous lesion is characterized by increased local temperature and that an older intraosseous lesion behaves the opposite, thus expresses itself with decreased temperature.

In order to clarify the term *intraosseous strain* (IOS), some quotes from Osteopaths are mentioned here:

> "Interosseous compressions are compressions between two bones; an *intraosseous* compression is a compression within the bone structure itself." (Handoll, 2000, p.89)

> "...the bone loses its capacity to diffuse or spread out the impact of stress." (Chauffour & Prat, 2002, p.47)

Philippe Druelle, DO qualitatively explains the intraosseous lesion as:

> "...la lésion est comme un trou noir qui aspire la vitalité des articulations en périphérie" and "...une zone de densité anormale qui donne une impression de plein et de vide en même temps. À la fois dense et homogène, un peu comme une pierre ponce." (as cited in Thibault, 2009, p.14)

Translated by Thibault DO (2009, p.14): “A zone of abnormal density which gives an impression of fullness and of a vacuum at the same time. At the same time dense and homogenous, a little like a sharpening stone."

IOS are usually not detected by common medical imaging methods, or in other words "not looked for" since this phenomenon - as described in osteopathic literature - is not considered in the medical profession. This might be also because most osteopathic IOS usually seem to be under the bone fracture threshold (Chauffour & Prat, 2002; Heller, 2011; Stone, 2002).

In reference to journal articles, books and other sources, little information is found on IOS. In osteopathic pediatric literature (Carreiro, 2009; Frymann, 1998; Liem et al., 2010; Sergueef, 2007), some authors write about IOS, but they mainly talk about this phenomena in immature bones of infants, especially in cranial bones such as the occiput, the sphenoid and the sacrum. They mention that in newborns and infants, many bones (their embryological segments) are not fused yet and that one can treat lesions / strains in between these segments and within these segments[3] itself. This present study solely involves adult subjects with matured tibial bones.

Also Sumner & Haines (2010) mention that one should "appreciate bones as dynamic living structures instead of dead, hard lumps of calcium". They elaborate on not yet ossified bones within infants and mention that forces generated by the birthing process might imprint on the biotensegrity structure of the cranial bones. Parts of these bones will be distorted in their arrangements leading to non-optimum shapes and movements in the fused adult bones. Sumner & Haines (2010) also talk about IOS within bones - even within adult bones - but

[3] As mentioned by Philippe Druelle DO in the teachings of Swiss International College of Osteopathy, there are so-called “intra-intra-osseous lesions” (within an embryological segment) and “inter-intra-osseous lesions” (in between two or more embryological segments)

they only mention the possibility that an IOS can be caused within the time frame before adult bony fusion.

J.H. Juhl (2005) mentions in a letter written in the Journal of the American Osteopathic Association that he often observes IOS in the os coxae of adult patients and talks about finding them and treating them with various methods, mainly with "peripheral application of the cranial concept". This method is not further elaborated on within that letter.

Chauffour DO & Prat DO (2002) and Heller DC (2011) are one of the few authors who talk about methodology in testing and treating IOS in adults. They offer an explanation for the nature of IOS, which run along the trabecular lines of force within the bone tissue. These intraosseous lines of force form a functional unity as they travel without interruption throughout the entire body. They refer to these osteopathic lesions as "lines of force fixities" and state that they are "classically ignored, [and] are one of the most important discoveries we have made in the last few years" (Chauffour & Prat, 2002). These fixations are concerned with both the transverse and longitudinal "lines of force". They build upon the osteopathic principle that micro-motions govern macro-motions in articulations, by proposing that intraosseous lines of force govern micro- and thus macro-motions (Chauffour & Prat, 2002). In an intraosseous line of force fixation, "the bone loses its capacity to diffuse or spread out the impact of stress" (Chauffour & Prat, 2002). Treatment is achieved through recoil techniques in which the parameters of force are accumulated, and then rapidly released.

Treatment of IOS will not be elaborated on in this thesis. It would be a very interesting follow-up study to compare thermal image patterns of intraosseous-strain-affected sites pre- and post-treatment.

2.3 THERMOGRAPHY IN RELATION TO THIS STUDY

Areas with altered skin temperature - either increased, decreased or with heterogenous distribution - can be shown effectively in thermal images. Baglin, Crocker, Timmins, Chandler & Boughton (1991) have shown that infrared thermography is a non-invasive and safe method of indirectly assessing peripheral blood circulation and even state that this technique may be used to study bone marrow blood flow for bone marrow disorders.

Current research in the medical field confirms that it is possible to detect abnormal physiological processes underneath and within the human skin with thermography. Main examples here are

- **Myelofibrosis** (Baglin et al., 1991). In this experiment, infrared thermography was used to assess bone marrow vascularity in six patients with myelofibrosis secondary to myeloproliferative disorders. It has shown that infra-red thermography (measurement device not specified) is a simple non-invasive method of assessing vascularity. This non-invasive technique could be used to study disease progression in patients with myelofibrosis and to study bone marrow blood flow also in other bone marrow disorders.
- **Bone cancer** (Amalric, Giraud, & Spitalier, 1974; Ebata, 1982; Farr, Laurent, Litvin, & Van Hasselt, 1982; Farrell, Wallace, & Edelken, 1968; Gardani, Bergonzi, Viganotti, Nessi, & Guzzon, 1983; Gudushauri, Venkhvadze, Giorgadze, Sepiashvili, & Gagulashvili, 1985; Pozmogov, Knysh, Chuvikin, & Leman, 1976; Trifaud, Amalric, Poitout, & Liegey-Bagarry, 1981; Wallace, 1974; Zweymuller & Strassl, 1973). Wallace & Edelken (1968) used a primitive thermograph with low temperature sensitivity (0.3˚ Celsius). Nineteen patients with osteosarcoma have been evaluated in two and a half years. In 14 patients, a primary tumor was clearly shown on the thermal readings. Metastatic tumors were frequently detected first with thermography, even when conventional roentgenography

showed no results. Gardani et al. (1983) retrospectively analyzed and statistically evaluated thermographic behavior of 168 malignant bone and soft tissue tumors between 1971 and 1981. It showed that in the group of malignant neoplasms, thermography reached a sensitivity 81.5%, even higher (but not significantly) in soft tissue tumors. The measurement device had low resolution but high sensitivity like the EC060 used in this experiment.

- **Breast cancer** (Amalric & Spitalier, 1975; Arora et al., 2008; Chudacek, 1977; Farrell, Wallace, & Mansfield, 1971; Keyserlink, Ahlgren, Yu, & Belliveau, 1997). In these studies, infrared thermography added new elements (in addition to classical methods as X-ray) in the systematic screening for cancer of the breast, in the early diagnosis of additional localizations (malignant cutaneous melanomas, uterine cervix, osseous sarcomas), in the check-up of extension of these cancers (in particular distant metastases) and especially in the study of their behavior and in their prognosis. For example, Amalric et al. (1974) used thermography on 351 patients with early breast cancer diagnosis and successfully detected its change in time with thermography by measuring heat emission of the breast's skin increased by cancerous activity underneath.

A thesis written by Ramakrishna R. Arumalla (2009) shows that it is possible to assess states of peripheral blood circulation with thermal imaging. Arumalla is a Electrical & Computer Engineer from MIT (Massachussets Institute of Technology) and wrote this thesis for his Masters degree in biomedical research. Arumalla (2009) and Vitetta, Johnson, Cortizo & Sali (2003) confirm the fact that skin temperature is a key indication of the presence of underlying medical conditions such as basal cell carcinoma, melanoma extensivity, deep vein thrombosis, diabetic foot, Raynaud‘s Syndrome, arthropathy and many other pathological conditions. Arumalla (2009) states that a decrease in skin temperature indicates a decrease in blood flow or vasomotor tone. His research (infrared imaging of testicular torsion of the spermatic cord which provides the blood supply to a testicle, performed on anesthetized sheep) confirms that under normal conditions in the animal body there is contralateral temperature symmetry, thus a temperature difference in symmetrically located regions indicates any kind of abnormality. Wu, Hamann, Salerno & Busse (2010) confirm this finding by performing a research visualizing a procedure which uses a compressor cuff to modulate blood flow in the upper extremities of humans.

Vitetta et al. (2003) performed an extensive literature review (178 research articles, providing level I/II/III/IV evidence[4]) and came to following conclusions concerning medical thermography:

- Thermography does *not* provide assessment in the degree of an illness.
- Thermography is a useful *adjuvant* screening procedure for a number of different medical problems.
- Thermography is capable of measuring *changes* in temperature that can *reflect* blood supply and inflammation which are general physiological changes.
- Thermography can only assess some aspects of peripheral blood flow.
- However, there is substantial scientific evidence that thermography can assess various aspects of peripheral blood flow, thus **microcirculatory disturbances can be clinically assessed by thermography** (Vitetta et al., 2003).

[4] "**Level I Evidence** is obtained from a systematic review of all relevant randomized controlled trials – meta analyses. **Level II Evidence** is obtained from at least one properly designed randomized controlled clinical trial. **Level III Evidence** is obtained from well designed controlled trials without randomization or from well designed cohort or case control analytic design studies, preferably from more than one centre or research group or from multiple time series with or without an intervention. **Level IV Evidence** represents the opinions of respected authorities based on clinical experience, descriptive studies or reports of expert committees." (Vitetta et al., 2003)

- **Thermography has been shown to be very reliable as a method of investigating skin blood flow** and as a screening method in the diagnosis of deep vein thrombosis (Hirata, Nagasaka, & Noda, 1989; Horzic, Bunoza, & Maric, 1996; Kohler & Hoffmann, 1998).
- Thermography has been used to evaluate the peripheral circulatory function in the diagnosis of diabetic complications (Mabuchi, 1990)
- Thermography in conjunction with Doppler sonography resulted in the highest diagnostic accuracy when investigating retrograde blood flow in the spermatic vein (Winsor, 1971)

It is important to note that thermography does not directly measure the flow of blood within its vessels (Doppler sonography does) but its thermal waves which the blood emits (Wu et al., 2010). They used an experiment setup with one test subject (N=1) which modulated the blood pressure by computer controlled application of air pressure to a compression cuff around the arm. The resulting field of blood flow modulation was monitored with a thermographic camera on the forearm.

These thermal waves emitted from the surface of the human body (skin) are a dynamic balance between hemodynamic and thermoregulatory processes (Zontak, Sideman, Verbitsky, & Beyar, 1998). Direct blood flow can be *estimated* by thermography, as shown in a study which estimates the coronary blood flow by thermography in open chest conditions (Gordon, Rispler, Sideman, Shofti, & Beyar, 1996). They used thermographic imaging on eight open-chest dogs which were injected with cold saline into the aortic root. As this experiment has shown, coronary flow could be estimated quantitatively by intraoperative epicardial thermography.

Plaugher et al. (1992) confirm that one can accurately measure skin temperature with thermal imaging, depending on the accuracy of the imaging device. The International Academy of Clinical Thermography (Thermology, 2003) gives exact specifications for devices which should be used for medical thermal imaging. Diadikes and Bronzino (2008), Ring and Ammer (Ring & Ammer, 2000) and Ring et al. (2004) give exact information on how to gain valid thermographical image material by standardization of image taking procedures for medical usage.

Research done on mice (Laing et al., 2007) shows that a musculoskeletal trauma directly initiates a pro-vascular response in the bone marrow, indicating that mechanical trauma of a bone and vasomotion[5] are directly linked with each other. 6 mice with a standardized, closed fracture of the femur and were analyzed. Measurement of cell-surface markers indicated the statement above.

The reason why this thesis wants to evaluate this measurement method is that manual thermal palpation is not as precise and objective as thermography. Although Barral DO (1996) states that manual palpation can give relatively exact information on the location of a change in temperature of the skin, but he also states that manual palpation is not precise in determining *how much* the temperature difference is. Murff, Armstrong, Lanctot, Lavery & Athanasiou (1998) even claim that manual palpation is not effective in detecting subtle temperature differences. Three medical doctors manually assessed inflammation sites of patients with diabetic and neuropathic issues. The outcome was that quantification of inflammation status was not possible by manual palpation only. This research tried to quantify manual palpation and tried to assess the inter-reliability of multiple examinators.

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[5] Vasomotion: "Change in the diameter of a blood vessel. Also known as angiokinesis." Source: http://www.answers.com/topic/vasomotion#ixzz1RvLjEbdn (accessed 12.09.2011). In the osteopathic world, vasomotion is defined as "capacity of the body to bring blood in each part of the body" (Druelle, 2011a)

The author believes that manual palpation is a very artistic and qualitative tool to perceive many kinds of information. But it might be impossible to quantify this information due to the fact that for one examiner a lesion might be perceived as "hard", and for the other examiner the same lesion might be perceived as "slightly hard".

The author suggests the possibility that one can quantitatively detect IOS with thermal imaging by finding altered average skin temperature on the affected site.

2.4 NORMAL SKIN TEMPERATURE OF THE ANTERIOR LOWER EXTREMITY

A quotation from A.T. Still DO (1910): "Temperature regulates the motion of the universe and all bodies therein. Life in motion is an effect of temperature just above 90 degrees Fahrenheit."

To be able to compare the found average skin temperatures to average skin temperature of the healthy population, we have to know what the normal average temperature of the anterior lower leg of a healthy adult is (baseline temperature). The author of this thesis performed a literature survey (Lee, Lee, Kim, & Kwon, 1997; Lukowitz et al., 2007; Uchida, 2001) on temperature readings of the lower extremities. The temperature measurement of the anterior skin of the tibial bone shown in observations by this author have a significant difference of 2,54 ˚C compared to the thermal readings of Lukowitz et al. (2007), Uchida (2001) and Lee, Lee, Kim, & Kwon (1997). These authors did not measure the anterior skin surface of the tibial bone and they all used punctual (and thus not average of a whole area) temperature measurement methods. According to this result, baseline temperature will be provided by the mean average skin temperature (MAST) of the control group of this study.

Within this research, the baseline temperature will be defined by the MAST of both anterior tibia's of all subjects within the control group, because there was no previous temperature measurements done on the anterior tibial skin surface next to unofficial observations done by the author (see table below).

Table: 3. AVERAGE TEMPERATURE OF THE LOWER LEG OF HEALTHY ADULTS - LITERATURE SURVEY

Authors	Mentioned average skin temperature
Lukowitz et al. (2007)	32,25 ˚C (skin temperature 15 centimeters above knee joint)
Uchida (2001)	33,92 ˚C (overall skin temperature of lower extremities)
Lee et al. (1997)	33,40 ˚C (overall skin temperature of lower extremities)
Temperature observations with 5 subjects by this author, performed in 2011	30,65 ˚C (overall skin temperature of the anterior surface of the tibia)

2.5 THERMOREGULATION OF THE SKIN

Because this thesis measures average skin temperature by thermography, one needs to know more about thermoregulation of the skin.

Thermoregulation is a neural process that matches information about the external environment with the appropriate response to maintain a more or less stable internal environment relative to external variation (Nakamura & Morrison, 2008). The several stages can be divided into (Seebacher, 2009):

- Sensation of environmental conditions and the internal thermal state.
- Transmission of this information to the brain through afferent neural pathways.
- Initiation of a response by efferent signals from the brain.

In humans, body temperature is regulated at the hypothalamus region of the brain (Gisolfi, D.R., & Nadel, 1993) which regulates body temperature to function within +/- 1 ˚C of resting temperature over each 24 hours cycle (Folk, Riedesel, & Thrift, 1998).

According to Lim, Byrne & Lee (2008), human body temperature is defined by its core and shell temperature. Core temperature refers to the temperature values of the abdominal, thoracic and cranial cavities, and shell temperature refers to the temperature values of the skin, subcutaneous tissue and muscles (Gisolfi & Mora, 2000). As stated above, core temperature is regulated by the brain (hypothalamus region).

For this thesis, shell temperature control is more interesting because this is being captured by the thermal camera. Shell temperature is influenced by skin blood flow and environmental conditions (Gisolfi & Mora, 2000).

Although humans are regarded as homeotherms[6] the dichotomy of body temperature into core and shell temperature is unique in that the core temperature is endothermic (regulated by the brain) whereas shell temperature is ectothermic (influenced by external environment) (Lim et al., 2008). According to Lim et al., shell temperature is "slave" to core temperature, both endo- and ectothermic properties function in synchronicity to maintain thermal balance within the body (Lim et al., 2008).

For this research, details about shell temperature mechanism is important to expand, since we look at the skin temperature captured by thermal imaging.

Heat transfer between the body and the external environment occurs through the following processes (Folk et al., 1998):

- Convection
- Conduction
- Radiation
- Evaporation

[6] An organism that maintains its body temperature at a constant level, usually above that of the environment, by its metabolic activity (TheFreeDictionary.com, 2001)

Heat transfer through convection, conduction and radiation is bidirectional, where heat transfer between the skin surface and the environment is driven by the temperature gradient between skin and its surrounding environment (Lim et al., 2008). Heat is transferred from the skin to the environment if the ambient temperature is lower than shell temperature and vice-versa.

As opposed to the above, heat transfer through evaporation is unidirectional, where heat is dissipated only from the skin surface to the external environment (Lim et al., 2008). Evaporative heat loss takes place when sweat changes from liquid to gaseous state. This is the main reason why within this study the subjects were being asked to not perform any sports activities on the day of the examination. Additionally, relative air humidity and room air temperature were held within limits to avoid any false temperature readings of the subjects skin.

2.6 MANUAL PALPATION OF SPRING AND VITALITY OF BONE TISSUE

In order to assess an IOS, one should test mechanical spring and vitality of a bone since an IOS contains decreased vitality and spring (Laflamme, 2006). Brown DOMP (2008) confirms this by saying that an intraosseous lesion is "... expressed by increased rigidity, altered force transmission, and reduced vitality".

Manual palpation will be used to locate and classify an existing IOS. An IOS is an osteopathic lesion which, as described by Denslow DO (1964, p.25) is a "discrete and unrecognized evidence of disturbance in the body framework which can be palpated (...) and which frequently seems related to signs or symptoms of illness...".

Andrew Taylor Still DO, as mentioned in a written introduction to special reprints in the Journal of American Osteopathy Association by Patterson DO (2000), was not concerned with symptoms, but with signs - the aspects of his palpatory sense told him of the functions of each individual structure. In relation to IOS it is important to mention this detail because, as often seen in patients treated by the author, they usually show an area of complaint next to or quite far away from an existing IOS.

2.6.1 Mechanical Spring of a Bone

Manual palpation of the spring of any tissue within the human body is the most important approach in Osteopathy. Osteopathy mainly relies on qualitative manual palpation of any tissue. The Swiss International College of Osteopathy teaches how to differentiate specific structures through several layers of tissue with distinctive palpation training in order to gain access to the targeted structure. In order to gain knowledge of the mechanical property of the tibial bone, one has to palpate *through* several tissue layers before palpating the bone itself (list from superficial to deep), clearly emphasized by Burns DO (Beal, 1989) in many lectures:

1. Skin
2. Subcutaneous tissue
3. Periosteum

After palpatory filtering out the layers mentioned above, the Osteopath will be able to test the spring of the tibial bone. As perceived by the author, a healthy bone feels like a green wooden branch of a tree: Alive, flexible, and humid. A bone area which has an IOS rather feels like a dead tree branch picked up from the ground: Dead, rigid, dry. Heller DC (2005) mentions: "Testing for intraosseous restriction is not really about motion, but rather about *give* or *stiffness*". Also Chauffour DO & Prat DO (2002) mention the importance of testing a bone through compressing along its longitudinal axis and along the so-called *Lines of Force* which are defined as specific areas within a bone which are more likely to have mechanical loading and thus are more prone to form IOS in mechanical trauma. Meert (2007) only mentions "intraosseous pumping" techniques, but no tests.

2.6.2 VITALITY

> "Vitality is the expression of life force in a body, and has many manifestations that can be observed and perceived by the experienced osteopath. Vitality, as the expression of life force, is at the interface of the union between the tangible, the physical body, and the intangible, the life force. It is the force that maintains health, achieves homeostasis, and accomplishes the work in osteopathic treatment." (Mummery, 2008, p.215)

Usually if the term *vitality* is mentioned in osteopathic literature (J. Licciardone, Brittain, & Coleridge, 2002; J. C. Licciardone et al., 2004; "Osteopathic Manipulative Therapy Helps Patients With Migraines," 2011; Rolf, 1989; Yahnert, Hartmann, Steward, & Kuchera, 2006), the author talks about *global vitality* of the patient which is being influenced through osteopathic interventions.

In the teachings of Swiss International College of Osteopathy (Beaulieu, Forget, Laflamme, & Lanthier, 2007; Beaulieu & Muzzi, 2004; Colford, Forget, Laett, Lanthier, & Van Vliet, 2005; Colford & Gauthier, 2004; Pelletier, Beaulieu, & Van Vliet, 2006; Pelletier & Colford, 2006) and mainly by its director Philippe Druelle, the term *vitality* is mentioned in a local, regional and global setting. This means that due to an IOS, an affected bone might express decreased vitality within itself but does not necessarily affect global vitality of the patient.

Diane Mummery, a DO from Ontario Canada, graduated from Canadian College of Osteopathy, presented a qualitative thesis with the title "An Analysis and Synthesis of the Concepts of vitality as they relate to Osteopathy" (2008) and defined vitality as follows:

> "As an interface, vitality is neither tangible nor intangible but something in between, with the qualities of both also of its own." (Mummery, 2008, p. 263)
>
> "...it is not static, but is an interface of resonance, which implies an exchange and interaction." (Mummery, 2008, p.263)
>
> "The nature of vitality is something that is perceived through the lens of the individual Osteopath." (Mummery, 2008, p.263)
>
> "The view of vitality is seen through a lens of experience and skill, paradigms, beliefs about the world, and expectations among other things." (Mummery, 2008, p.263)
>
> "Vitality is never ill. The perception of the expression of vitality through the body can be distorted by barriers, blockages or restrictions. In Osteopathy, the removal of restrictions and blockages allows for the free expression of vitality." (Mummery, 2008, p.264)
>
> "The expression of vitality implies motion. However, the motion that occurs is the result of the effect of vitality on matter, ..." (Mummery, 2008, p.264)
>
> "In the perception of vitality, the energy of intention of the Osteopath could change the expression of the vitality just through the act of observation." (Mummery, 2008, p.264)
>
> "The perception of vitality cannot be taught; it must be experienced. The experience of vitality is a knowing or resonance." (Mummery, 2008, p.265)
>
> "Vitality is part of the whole expression of the universe with no divisions or boundaries." (Mummery, 2008, p.265)

Diane Mummery DO (2008) used three styles of research: *Documentary-historical* style for literature review; *survey* style for all web-site accessible global English language osteopathic colleges, and for practicing osteopaths by questionnaire; and *unstructured interviewing* with osteopathic elders. *Complete* sampling was used for the osteopathic colleges, and *theoretical* sampling was employed for the English-speaking osteopathic community and the 34 osteopathic elders (internationally known Osteopaths as Jean-Pierre Barral DO, Rachel Brooks MD, Anthony Chila DO FAAO FCA, Colin Dove DO, Philippe Druelle DO, Viola Frymann DO FAAO, Nicolas Handoll DO, James Jealous DO, Michael Kuchera DO FAAO, Harold Magoun Jr. DO FAAO FCA, Renzo Molinari DO, Robert Rousse DO, Karen Steele DO FAAO and many more) with a minimum of 20 years experience.

According to Druelle DO (2011a), the expression (expansion and retraction of the tissue) of vitality happens simultaneously to the Cranial Rhythmic Impulse[7] (CRI). This would correspond to the findings of K.E. Nelson et al. (2006). Much osteopathic research has been done on the *Cranial Rhythmic Impulse* or also called *Primary Respiratory Mechanism*.

Nelson, Sergueef, Lipinski, Chapman & Glonek (2001) compared manual palpation of the CRI and simultaneous measurement of the Traube-Hering-Mayer (THM) oscillation by Laser-Doppler Flowmetry and came to the result that both CRI and THM happen simultaneously, though they may not represent the same phenomenon. THM are waves in arterial blood pressure brought by oscillations in baroreceptor and chemoreceptor reflex control systems (Nelson et al., 2001). These waves are seen both in electrocardography and in blood pressure curves and have a frequency about 0.1 Hz (6 waves/minute).

Kenneth, Sergueef & Glonek (2006) compared quantified rates for the CRI reported in the literature from 1961-2006. They found that in most publications where manual palpation was used to obtain data, the reported rate of CRI was 3-9 cycles per minute (cpm). In publications where data was obtained by any kind of instrumentation, the rate of CRI was measured 7-14 cpm.

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[7] CRI = Cranial Rhythmic Impulse, also called *Primary Inspiratory Mechanism* or *Cranial Motion* (Druelle, 2011a; Laflamme, 2006; Nelson et al., 2006)

Within a study examining CRI (Nelson et al., 2006), the conclusion was that CRI palpated manually was half of the rate of the instrumentally tested THM oscillation, thus indicating that CRI and THM might not be the same phenomenon and more research should be done in this area.

Druelle DO (2011a) teaches that vitality is being sensed as an expression of expansion and retraction within the tissue. The American Dictionary of the English Language (Dictionaries, 2000) defines the term *vitality* as such:

- The capacity to live, grow, or develop
- Physical or intellectual vigor; energy
- The characteristic, principle, or force that distinguishes living things from nonliving things
- Power to survive

The term *vitality* is derived from the word *vigor* (middle english), which is again derived from the latin word *vigere*, which can be translated as "to be lively" (Dictionaries, 2000). So this concludes that with vitality, we try to palpate *direct expression of life*. As Rollin E. Becker DO (1997, p.95) quotes:

> "Motion is not life. Motion is a manifestation of life."

Furthermore, Andrew T. Still DO (1899, p.69) gives us the following important message:

> "Every joint of the neck and spine has much to do with a healthy heart and lung, because all vital fluids from crown to sacrum do or have passed through heart and lungs, and any slip of bone, strain or bruise will affect to some degree the usefulness of that fluid in its vitality, when appropriated in the place or organ it should sustain in a good healthy state. To the osteopath, his first and last duty is to look well to a healthy blood and nerve supply."

These two sentences reinforce the importance of the expression of local, regional and global vitality in general and also the importance of the fluids, with which the author wants to indicate in this thesis that vitality might have an influence on the nature of IOS.

2.7. Osteopathic Justification

In this subchapter, the following important osteopathic topics such as

- Still DO and bones;
- intraosseous fluid flow;
- osseous mechanotransduction;
- anatomy and physiology of the tibial bone;
- vasomotion;
- segmental reflexology of the tibial bone and its surrounding tissues;
- embryological development of the tibial bone;
- energetic anatomy of the lower extremities;
- energetic aspects of mechanical trauma

will be discussed. Any of the mentioned subjects above may contribute to understand the phenomenon of IOS.

2.7.1 A.T. Still and his Relation to Bones

As documented by Hildreth DO (Liem, Sommerfeld, & Wührl, 2008), A.T. Still DO often carried along a bag full of human bones and was able to put them together in accordance to their articular surfaces. He could even say if a bone was from the left or the right side of the body by simply feeling their shape. In all his books he stressed the importance of the normal position and inter-mobility of all bones (Liem et al., 2008; 1899, 1910).

A.T. Still DO also elaborated on the creation on the name of his treatment method, Osteopathy (Still, 1897, p.221):

> "You wonder what Osteopathy is; you look in the medical dictionary and find as its definition "bone disease". That is a grave mistake. It is compounded of two words, osteon, meaning bone, pathos, pathine, to suffer. Greek lexicographers say it is a proper name for a science founded on a knowledge of bones. So instead of "bone dis-ease" it really means "usage"."

Additionally it might be important to note that historically seen, the "ancestors" of Osteopaths were so-called *bone-setters* (Liem et al., 2008), thus already then the term "bone" was used for this treatment approach.

2.7.1 Fluid Flow within Bone Tissue

It makes sense to anticipate the possibility that fluid flow within the bone tissue might affect its temperature and the tissue around it. Any increased physiological activity also affects tissue temperature positively (Diadikes & Bronzino, 2008), shown mainly by cancerous processes within bone and other tissue (Farrell, Mansfield, & Wallace, 1971; Farrell et al., 1968; Farrell, Wallace, et al., 1971) which - next to increased blood flow - also increases general physiological activity. Julie Brown DOMP (2011) - the author of a qualitative thesis about IOS and interosseous compactions - suggests that an IOS affects fluid flow within the bone tissue. A short literature research on bone tissue fluid flow is therefore given:

Hillsley and Frangos (Hillsley & Frangos, 1994) and Fleming et al. (Fleming et al., 2001) state that optimal interstitial fluid flow directly affects bone cell function and bone remodeling. The composition of bone fluid within the bone fluidic compartment seems to be regulated by a blood-bone barrier, formed mainly by (pre)osteoblastic cells (McCarthy &

Hughes, 1987). Within quiescent[8] bone tissue, numerous intercellular small channels (2 nanometers diameter) have been observed (Doty, 1981) which are actually even larger in diameter than in active remodeling bone (Holtrop, 1990). Hillsley and Frangos (1994) state that this bone-blood barrier may regulate the rate of calcium absorption which affects the intercellular channels, and thereby regulate the flow rate within the bone matrix. This increased flow may even influence other bone cells deeper within the matrix.

Hillsley and Frangos (1994) say that a significant and rapid fluid flow occur through the interstitial spaces of bone. The interstitial fluid is driven from the endosteal[9] toward the periosteal[10] surfaces in cortical bone. The flow appears mainly to be driven by a hydrostatic pressure drop across the cortex, resulting in an outward radial flow (Hillsley & Frangos, 1994). Because lymphatics are absent from the bone marrow (Tavassoli & Yoffey, 1983), this pressure drop towards the exterior surface of the bone is crucial so that all fluids can be drained towards the periosteal surface where the lymphatic system is present (Anderson, 1960).

Kelly & Bronk (1990) showed that increased venous and intraosseous pressure resulted in an increase in extracellular fluid and fluid space, thus suggesting that this causes an increase in interstitial fluid flow.

Correlations between mechanical aspects and water content in cortical bone was measured by Bae et al. (2011) with ultrashort echo time (UTE) magnetic resonance imaging. They found a positive correlation between porosity and total water content, and more important to note a negative correlation between "ultimate stress" (maximum possible mechanical stress

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[8] quiescent = state of absent active remodeling

[9] endosteum = thin layer of connective tissue that lines the surface of the bony tissue that forms the medullary cavity of long bones (Netter, 1987)

[10] periosteum = a membrane that lines the outer surface of all bones, except at the joints of long bones as the tibia (Netter, 1987)

before fracture) and total water content of bone tissue. This result indicates that the more "fluidic" a bone is, the lesser force is needed for a fracture. This result makes sense in connection to the first correlation: The more water within a bone, the more porous the bone. The more porous the bone, the weaker its mechanical properties.

Osteopathically seen, one might assume that this should be the opposite. But here again is a difference in definition of words like "fluid". A medical reasearcher quantitatively measures the amount of fluids within a bone (Bae et al., 2011), and an osteopath subjectively perceives the "fluidity" of a bone. These two measurement methods are very different form each other and surely give different results and interpretation.

2.7.2 MECHANOTRANSDUCTION WITHIN BONE TISSUE

Mechanotransduction is a molecular mechanism by which cells sense mechanical forces and convert them into changes in intracellular and gene expression (Ingber, 2008). The concept of mechanotransduction might explain the physiological process which happens during the creation of an IOS. According to Jerosch, Bader & Uhr (2002), this process helps the bone to adapt to new mechanical demands which occur through several steps shown here:

1. During mechanical coupling, mechanical forces are being converted into local signals which can be transferred towards bone cells. This process activates certain biochemical reactions within osteocytes and bone lining cells. Accountable for this step are stress-induced lacuno-canalicular fluid flows, respectively shearing forces within fluids of the lacuno-canalicular network in the bone.
2. Following step one, the biomechanical coupling - transduction of a mechanical signal into a biomechanical reaction - takes place. This process is being

contributed by some metabolic pathways within the cell membrane and the cytoskeleton.

3. Now, sensor cells (most probably osteocytes and bone lining cells) pass on these signals to effector cells (osteoblasts and osteoclasts) through signal molecules, so-called prostaglandines and nitrogen peroxide.
4. In the end, we have the actual reaction of the effector cells; bone formation or bone decomposition.

These processes could explain why a bone is being perceived as more rigid by an Osteopath because the bone tissue induces bone formation after a mechanical stimulus. But Jerosch et al. (2002) mention that a one-time mechanical stimulus does not create bone formation (unless there is a fracture), but rather repetitive stimuli. This fact implies that maybe IOS created by repetitive mechanical microtrauma due to compensation mechanisms or other mechanisms could be explained by these mechanotransductory processes?

2.7.3 Anatomy and Physiology of the Tibia

It is very important to state that not only gross anatomy of the bone tissue (like morphology, innervation, vascularization, histology and cytology) is important, but specifically the physiology and micro-anatomy of what happens *inside* the bone!

Much information for this subchapter was taken from Jerosch et al. (2002), a book specifically written about osseous physiology. Bones are mainly made of extracellular/ organic bone matrix[11] and bone cells (osteocytes, osteoblasts and osteoclasts).

[11] Author‘s note: organic bone matrix is also called "osteoid" (Jerosch et al., 2002)

2.7.3.1 EXTRACELLULAR MATRIX

Organic bone matrix is 90% to 95% made of Type-I collagen, which is synthesized by osteoblasts and chondrocytes[12] and has following functional characteristics (Van der Rest & Garrone, 1991):

- Mechanical stability
- Compressive strength
- Tensile strength

Further proteins in the bone matrix are osteocalcin, osteonektin, bone proteoglycans, proteolipids, sialoprotein and bone morphogenetic protein (Jerosch et al., 2002).

2.7.3.2 OSTEOCYTES, OSTEOBLASTS AND OSTEOCLASTS

Osteocytes develop from osteoblasts, have a size of 20-60 micrometers and are found in small lacunae amidst mineralized bone substance. They are interconnected with other osteocytes through cellular extensions and create a osteocyte-syncytium[13]. Osteocytes mainly participate in intercellular communication, mineral-matter homeostasis and mechanotransduction (see chapter 1.3.) (Jerosch et al., 2002).

Osteoblasts create non-mineralized intercellular substance called osteoid within bone tissue. These bone generating cells originate from mesenchymal stem cells. They are about 20 micrometers in diameter and have a single cell nucleus. Osteoblasts line up on the surface of bone lining cells like a string of beads and produce organic bone matrix. They also secrete great amounts of alkaline phosphatase which prepares the organic bone matrix for mineralization. Among others, osteoblastic activity is being regulated by bone morphogenetic

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[12] chondrocytes are only found in cartilage (Jerosch et al., 2002)

[13] syncytium - a mass of cytoplasm containing several nuclei and enclosed in a membrane but no internal cell boundaries (Farlex, 2001)

protein, parathormone, estrogens and steroid hormones. After osteoblasts have fulfilled their function, they either become osteocytes (immured in organic bone matrix) or cover cells on the osseous surface. This conversion process only affects about 30%-50% of all osteoblasts, 50%-70% die through apoptosis[14] (Jerosch et al., 2002).

Osteoclasts - cells which break down bone tissue - have a size of about 100 micrometers and contain up to 100 cell nuclei. Usually they appear on the surface of bone tissue. Osteoclasts break down bone tissue by secreting strong acids and "dig" tunnels which are called Howship-Lacunae. Secretion of special proteases again allow the breaking down of the organic bone matrix (Jerosch et al., 2002).

2.7.3.3 TYPES OF BONE AND THEIR SPECIFIC ARCHITECTURE

Within the human bone system there are two types of bone: Woven and lamellar bone.

2.7.3.3.1 WOVEN BONE

When new bone tissue is being formed in the development of the fetus or after a fracture within the callus, collagenous fibers are being assembled in a seemingly random configuration. Through mineralization of this bone matrix, a mesh of trabeculae is being formed - the woven bone. At time of birth this type of bone predominates (Schünke, Schulte, & Schumacher, 2005).

2.7.3.3.2 CONVERSION OF WOVEN BONE INTO LAMELLAR BONE

Medullary cavities within the woven bone tissue are relatively large and contain 1-2 capillary vessels, perivascular cells and one nerve fiber. These trabeculae together with medullary cavities are being called *primary osteon*. Within the cortical region, osteoblasts

[14] apoptosis - a natural process of self-destruction in certain cells that is determined by the genes and can be initiated by a stimulus or by removal of a repressor agent. Also called *programmed cell death* (Farlex, 2001)

deposit bone substance by creating concentric layers in a lamellar-like form until almost all medullary cavities are filled (Schünke et al., 2005).

After this process, small canals (Havers-Canals) with a diameter of about 50 micrometer, a small artery, a small venule and one nerve fiber remain. All Havers-Canals are connected with each other by Volkmann-Canals (Schünke et al., 2005). Now this system is called the *secondary osteon*, respectively the Havers-System. The Havers system consists of 4-20 concentric cylindrical lamellae with a thickness of 3-6 micrometers. Through creation of countless secondary osteons, lamellar bone is being formed. During this transformation process the medullary cavities are being preserved. Red hematogenous bone marrows are generated from their mesenchymal cells (Schünke et al., 2005).

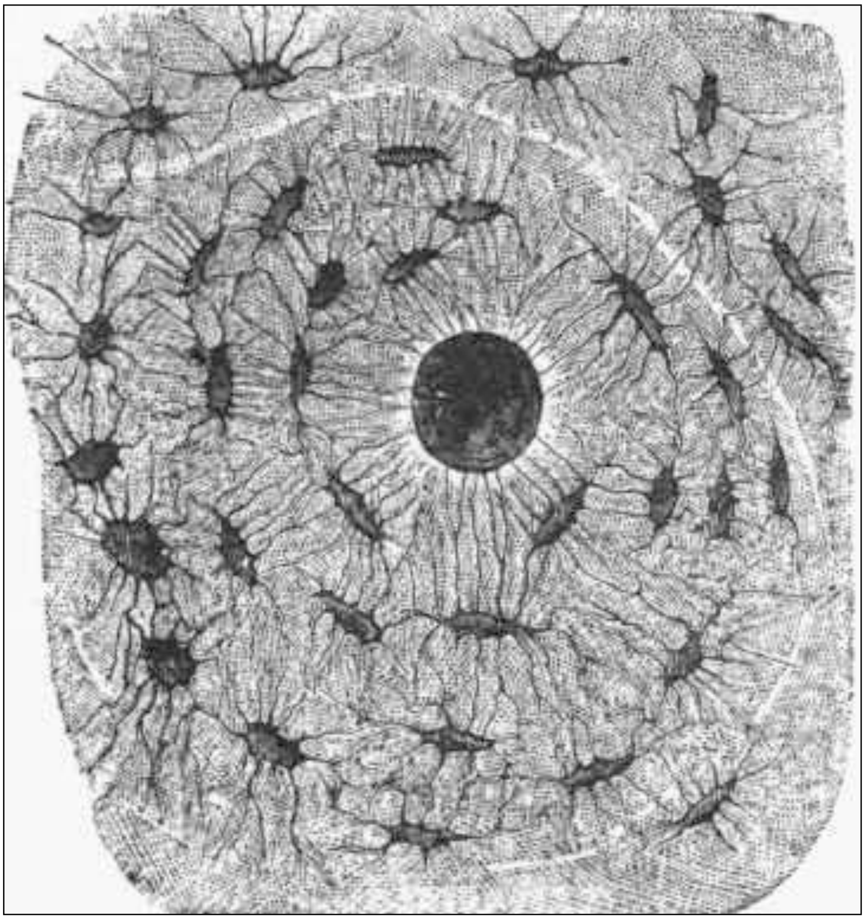

Figure: 2. Transverse section of a system of Havers, showing Haversian canal in centre, with bone cells arranged around it in lacuna (Schünke et al., 2005).

2.7.3.3.3 LAMELLAR BONE

Lamellar bone is made of cortical (or: compact) and cancellous (or: spongiosa) bone. Cortical bone is located at the outer area of a bone, cancellous bone is found within.

Cortical bone covers cancellous bone like a shell and is made of lamellar bone tissue which is being formed by the combined effect of endosteal and periosteal bone conversion (Schünke et al., 2005). Within each lamella of the secondary osteon, the orientation of collagenous fibers and calcium-phosphate crystals changes. This way a complex and plywood-like structure with excellent biomechanical properties is being created (Weiner, Traub, & Wagner, 1999). This structure is predominant within cortical bone and is 80% of total bone mass of the human skeleton (Schünke et al., 2005).

Cancellous bone is also made of lamellar bone, it is 20% of total bone mass of the human skeleton (Schünke et al., 2005). This complex sponge-like construction is made of connected and intersected, straight and curved trabeculae. Cancellous bone is especially found in the endings of long bones, in the skullcap and in cube-like bones (e.g. vertebrae). Cancellous bone is metabolically more active and reacts faster on mechanical and metabolical stimulations (Schünke et al., 2005).

Noteworthy is that there is no clear evidence on the close connection between elastic properties of the cancellous bone and the linkage density of its trabecular structure (Kabel, Odgaard, van Rietbergen, & Huiskes, 1999; Kinney & Ladd, 1998). Also bone mineral density (BMD) alone does not reflect its strength, rigidity and elastic property. But according to Kabel et al. (1999), trabecular bone volume showed highest positive correlation with bone strength and rigidity.

2.7.3.4 GROSS ANATOMY AND PHYSIOLOGY OF THE TIBIA

According to Gray's Anatomy Atlas (Drake, Vogl, Mitchell, Tibbits, & Richardson, 2008), the tibia, or also called shinbone, is commonly recognized as the strongest weight bearing bone in the body. It is the second largest bone in the human body, the largest being the femur. Proximally, it articulates with the femur, the patella and the proximal fibula via the tibiofibular joint (Schünke et al., 2005). Distally, the tibia articulates with the talus and the distal fibula via the tibiofibular syndesmosis (Schünke et al., 2005). Between the tibia and the fibula, we find the interosseous membrane (membrana interosseus cruris). This interosseous membrane is made of a tight connective tissue lamina which acts as an anchor for various muscles and stabilizes the malleolar fork (Drake et al., 2008).

2.7.3.4.1 ARTERIAL SUPPLY

Main incoming arteries into the periosteum of the tibia are (Menck, Bertram, & Lierse, 1992):

- Anterior and posterior recurrent tibial arteries (arteriae recurrentes tibialis ant./ post.)
- Medial and lateral inferior genus arteries (arteriae inferiores genus med./lat.)
- Anterior and posterior tibial arteries (arteriae tibialis anterior and posterior)
- Semicircular vessels of the anterior tibial artery (arteria tibialis anterior)
- Fibular artery (arteria fibularis)

These arteries all arise from the following branches (Schünke et al., 2005), listed from proximal to distal: Femoral artery - popliteal artery - anterior tibial artery, posterior tibial artery and fibular artery.

According to Menck et al. (1992), the tibia can be divided into four segments:

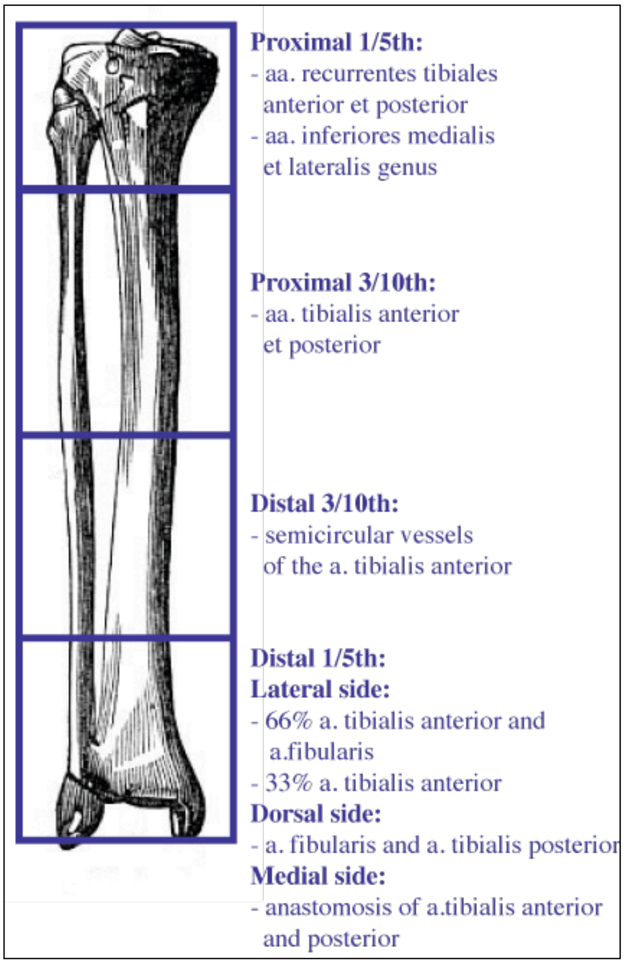

Figure: 3. Angioarchitecture of the tibia (adapted from Menck et al., 1992)

According to the figure above, it seems that the anterior tibial artery is of great importance concerning the arterial supply of the periosteum and the outer aspect of the cortex of the tibia (Menck et al., 1992).

This anatomical detail brings forth the question if an IOS is affected by its arterial supply or not. If yes, one could observe regional (see Figure 3 above) temperature changes because the anterior tibial artery supplies most of the tibial bone. As observed by the author within this research, an IOS creates a regional decrease in temperature, thus respectively decreasing each area of the tibia by a certain amount of degree Celsius, and not just on a local spot just where an IOS is.

2.7.3.4.2 VENOUS DRAINAGE

Following veins drain the blood from the tibia (Schünke et al., 2005):

- Posterior: Posterior tibial veins (venae tibiales posteriores)
- Anterior: Anterior tibial veins, large saphenous vein, genicular veins (venae tibiales anteriores, vena saphena magna, venae geniculares)

These veins drain into the following proximal veins, from distal to proximal (Schünke et al., 2005): Genicular veins, anterior and posterior tibial veins - popliteal vein - external iliacal vein. The large saphenous vein drains directly into the external iliacal vein.

2.7.3.4.3 LYMPHATIC DRAINAGE

Lymphatics are absent from the bone marrow (Tavassoli & Yoffey, 1983), thus lymphatic drainage only starts at the cortical bone.

Superficial and deep lymph vessels drain into popliteal vein and vena saphena parva. Along the vena saphena parva we find lymphatic nodes, the so-called noduli popliteales superficiales. Vena poplitea and vena saphena parva drain into the vena femoralis where we find the noduli popliteales profundi. These lymphatic nodes are the main collecting nodes for the tibial region. Vena femoralis the drains into vena iliaca externa, then vena cava inferior (Schünke et al., 2005).

As Druelle (2012) stated that an IOS creates a change in fluid flow within the bone, thus describing the mechanism of flymphatic drainage within bone tissue is important to mention here. It seems apparent that the more increased lymphatic drainage activity a bone has, the more fluidic activity there is.

2.7.4 SEGMENTAL REFLEXOLOGY OF THE ANTERIOR TIBIAL REGION

In the developing vertebrate embryo, a segmental setup of the mesoderm are called somites. There is a total of 31 somites (8 cervical, 12 thoracic, 5 lumbar, 5 sacral and 1 coccygeal) (Blechschmidt, 2004). From this tissue layer, following segmentally divided tomes are being developed (Van Cranenburgh, 2000):

- **Mesoderm**:
  - A part of the Dermatome: Especially subcutaneous tissue layers
  - Myotomes: The skeletal musculature (its motor units)
  - Sclerotome: Capsule tissue, ligaments, connective tissue and bone (osteotome)

On the other hand, the endoderm is an unsegmented duct running from the mouth to the anus. This tissue is divided into the following segments:

- **Endoderm**:
  - Viscerotome: (also called Enterotome) The inner organs
  - Angiotome: The blood vessels

Also the ectoderm is a covering tissue only segmented by its innervation secondarily:

- **Ectoderm**:
  - A part of the Dermatome: Superficial layer of the dermis
  - Sudotome: The sweat glands

The human body has 31 spinal nerve pairs which pass through the intervertebral foramina of the spinal column. Each spinal nerve pair supplies a unique bilateral segment divided in tomes as mentioned above (Van Cranenburgh, 2000; Wancura-Kampik, 2009).

In relation to the tibial bone and its overlying tissues, it is important to show all but one (the viscerotome) tome which might directly or indirectly affect the anterior tibial area and thus might change thermal radiation of the skin.

Van Cranenburgh (2000) performed an extensive literature research and demonstrated that all the mentioned tomes are not clearly defined in their exact location. Many authors (from the 19th century on) and their anatomical mappings are shown in his publication. Van Cranenburgh (2000) and Wancura-Kampik (2009) both emphasize that most tomes overlap each other slightly and that these areas are not exactly the same in each person.

2.7.4.1 THE ANTERIOR TIBIAL REGION AND ITS RELATED DERMATOMES

A dermatome is an area of skin in which sensory nerves derive from a single spinal nerve root. In the publications of Van Cranenburgh (2000) and Wancura-Kampik (2009) which show dermatome maps of many different authors from the year 1893 (Moll van Charante, G.H.: De hyperalgetische zones van Head. Original book not possible to retrieve) up to 1979 (Chusid, 1978). A study of these maps revealed that the anterior tibial surface is mainly related to the segments L4 and L5 and, very little is also related to segment S1, near the foot laterally. See figure 4 for detailed map.

2.7.4.2 THE ANTERIOR TIBIAL REGION AND ITS RELATED MYOTOMES

Each muscle in the body is supplied by a one or more levels or segments of the spinal cord and by their corresponding spinal nerves. A group of muscles innervated by the motor fibers of a single nerve root is known as a myotome. According to Chusid (1978), the anterior muscles of the tibial area are related to the segments L5 and S1, partially S2 (gastrocnemius muscle, can be partially seen from an anterior view). See figure 4 for detailed map.

2.7.4.3 THE ANTERIOR TIBIAL REGION AND ITS RELATED SCLEROTOMES

A sclerotome is the part of the segmented mesoderm layer in the early developing embryo that originates from the somites and gives rise to skeletal tissue of the body. Wancura-Kampik (2009) show detailed maps of all sclerotomes:

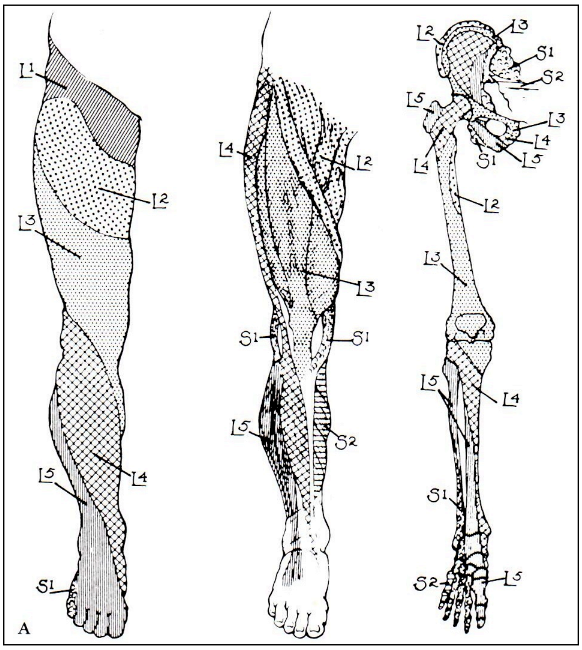

Figure: 4. Sclerotomes of the lower extremities (Van Cranenburgh, 2000)

The anterior part of the tibial bone is related to the following segments:

- L3: antero-medial part of the proximal tibia
- L4: proximal parts of the tibia
- L5: fibula and distal parts of the tibia
- S1: distal part of the fibula

2.7.4.4 THE ANTERIOR TIBIAL REGION AND ITS RELATED SUDOTOMES

A sudotome is the part of the segmented ectoderm layer in the early developing embryo that originates from the somites and gives rise to the sweat glands of the skin.

Van Cranenburgh (2000) compiled a couple of authors regarding sudotomes and came to the result that all sweat glands are related to the segments T9-L2.

2.7.4.5 The anterior tibial Region and its related Angiotomes

Angiotomes are segment areas innervated by the ortho-sympathetic autonomic nervous system, controlling its vasomotion (Van Cranenburgh, 2000). Segments T9-L2 are mainly responsible for the legs.

2.7.4.6 Summary

Somatically related segments to the anterior area of the tibia are **(L3), L4, L5, (S1) and (S2)**. The segments surrounded by brackets are only partially important for this specific area. Sympathetically related segments to the anterior area of the tibia are **T9-L2**.

A somatic lesion to any of the above mentioned segments could lead to a change in physiological activity (esp. blood circulation) in the anterior area of the tibia which might affect skin temperature. No assessment of the mentioned segments was performed by the author before thermal imaging and osteopathic examination within this research. This fact could lead to the assumption that some temperature values measured might be influenced by efferent reflex mechanisms.

2.7.5 Vasomotion

In this chapter, we try to create a bridge between structural anatomy, segmental anatomy and the probable nature of an IOS.

As stated in the subchapter before, the anterior tibial skin region is being controlled by spinal nerves coming from segment L4 and L5, especially on the dermatome level. Sympathetically, blood flow and thus vasomotor control is being directed by the segments T9-L2. Each blood vessel has a smooth muscle layer which is being controlled by the autonomous nervous system and by certain hormones (Druelle, 2009).

Dain Tasker DO (1903) defines an osteopathic lesion as following and therefore also stresses the importance of proper vasomotion and optimal blood flow in any tissue:

> "The lesion is an obstruction to blood supply, which equals a changed metabolism in the immediate area, resulting in irritation to the nerves in the immediate area either as result of pressure or lack of proper food. This is followed by an altered blood supply in distant reflex areas through actions of vasomotor nerves causing changed metabolism in said distant or reflex areas, resulting weakened tissue through lack of proper exchange of food and waste elements. This decreases resistance to bacteria, hence opens the way to specific infection."

Additionally, vasomotor activity is defined as following:

> "La vasomotion se manifeste par des oscillations rythmées dans le tonus vasculaire qui se concrétise localement par des variations dans la contraction et de la dilatation des muscles lisses, plus particulièrement dans les parois des artères." (Druelle, 2009)
>
> Translation by the author: "Vasomotion manifests via rhythmic oscillations within the vascular tonus which shows itself by variations of contraction and dilatation of the smooth muscles, and especially in the arterial walls."

Druelle DO mentions that an IOS may cause a change in vascularization:

> "A change inside of living bony tissue, expressed by change in mechanical resistance (spring); change in vascularization; change in fluid flow; change in its surrounding/perfusing electro-magnetic field; and a change in local Primary Respiratory Motion." (Druelle, 2012)

This could be induced either by local mechanisms, by vasomotion processes or by sympathetic nerve control mechanisms.

2.7.6 EMBRYOLOGICAL DEVELOPMENT OF THE TIBIAL BONE

According to White (2000), the tibia ossifies from three centers: One for the shaft and one for each end of the bone. Separate centers for the tibial tuberosity sometimes occur. Ossification centers originate within *detraction fields* (Blechschmidt, 2004) where connective tissue becomes increasingly tensed and viscous due to cartilage growth. Under this traction, the viscous connective tissue expulses its fluids and a hardening of the intercellular ground substance occurs.

The moment when all secondary ossification centers[15] are finished producing bone tissue and the epiphyseal plate is fused, length growth of the bone is finished (Schünke et al., 2005). White (2000) shows that the proximal tibia fuses between the age of 18 and 21, the distal tibia fuses between the age of 18 and 20.

Knowledge about fusion of the tibial ossification centers is crucial for this research because the author wanted to avoid any distortion of temperature values due to increased physiological activity by bone formation processes. Complete fusion of the tibial bone until the age of 21 leads to the inclusion requirement of minimum age of 22.

2.7.7 ENERGETIC ANATOMY OF THE LOWER EXTREMITIES

It is questionable if it is necessary to describe the Human Energy Field in relation to this thesis. The author seriously doubts that thermal imaging can measure all frequencies emitted by the Human Energy Field, mainly due to the fact that only thermal radiation between 8-14 micrometers are being recorded by the Trotec EC060 thermal camera. This infrared range of radiation is only a small part of all existing radiation wave lengths.

As mentioned by Heller DC (2005), an IOS creates a sensation of a "magnetic pull" towards the bone. Clinical experience of the author confirms this sensation. He describes it as

[15] these centers are built after birth within cartilaginous epiphysis and apophysis

being "attracted by a suction force" or by an area of "lack of energy" which magnetically attracts its surrounding energies.

As defined by Brown DOMP (2008), an IOS is partially defined by its lack of vitality. In chapter 2.6.2, vitality is described as "the expression of life force in a body“" (Mummery, 2008). This "life force" will be described below, published by Barbara Ann Brennan, an authority in reading the Human Energy Field.

According to Brennan (1988), the Human Energy Field is the manifestation of universal energy that is intimately involved with human life. "It can be described as a luminous body that surrounds and interpenetrates the physical body, emits its own characteristic radiation and is usually called the *aura*" (Brennan, 1988). She says that these fields or bodies surround each other in successive layers. Each succeeding body is composed of finer substances and higher vibrations than the layer that it surrounds and interpenetrates.

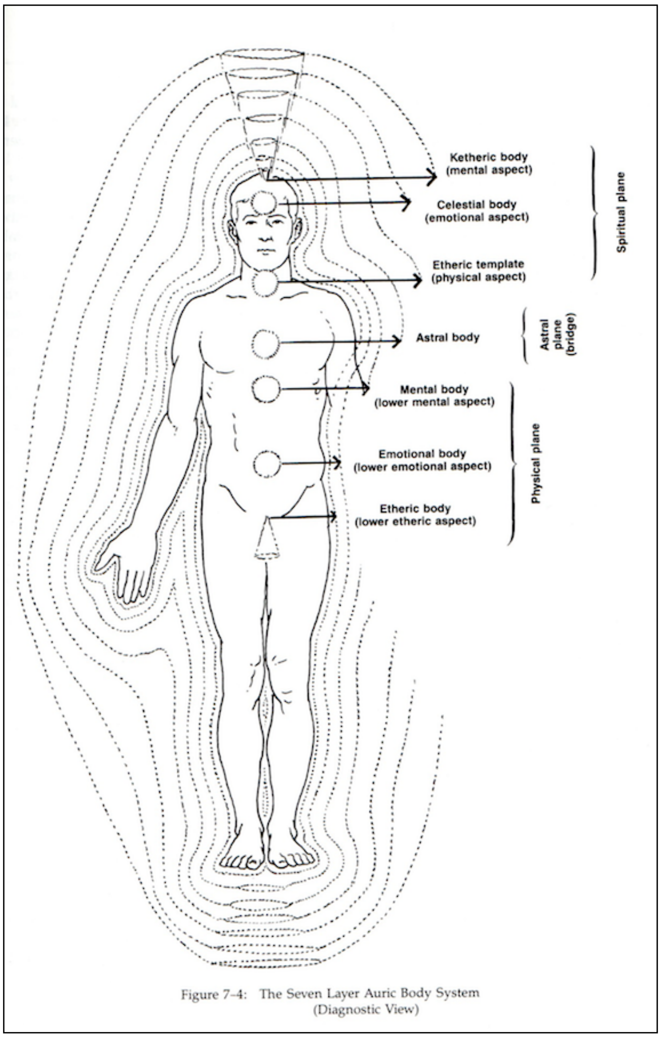

Figure: 5. The Seven Layer Auric Body System (diagnostic view) by Brennan (1988)

According to Brennan (1988), the human life field, also called aura, is divided into seven auric layers (ordered from center to periphery):

1. The Etheric Body
2. The Emotional Body
3. The Mental Body
4. The Astral Level
5. The Etheric Template Body
6. The Celestial Body
7. The Ketheric Template or Casual Body

Each layer/body is correlated with a specific energy center, a chakra. Each chakra converts incoming primary energy[16] and nourishes parts of the human system:

Table: 4. MAJOR CHAKRAS AND THE AREA OF BODY THEY NOURISH (ADAPTED FROM BRENNAN, 1988)

Chakra	Auric layer	Endocrine Gland	Area of Body governed
7: Crown	The Ketheric Template or Casual Body	Pineal	Upper brain, right eye
6: Head	The Celestial Body	Pituitary	Lower brain, left eye, ears, nose, nervous system
5: Throat	The Etheric Template Body	Thyroid	Bronchial and vocal apparatus, lungs, alimentary canal
4: Heart	The Astral Level	Thymus	Heart, blood, vagus nerve, circulatory system
3: Solar Plexus	The Mental Body	Pancreas	Stomach, liver, gall bladder, nervous system
2: Sacral	The Emotional Body	Gonads	Reproductive system
1: Base	The Etheric Body	Adrenals	Spinal column, kidneys

In connection with this thesis, it is necessary to mention that every layer has influence on each physical structure and its function, just on a different level. Brennan (1988) mentions that a disturbance of the base chakra might influence body temperature of the lower extremities, especially the feet. No energetic assessment was performed before infrared imaging of the subject to avoid any distorted temperature readings, and no energetic assessment was performed during osteopathic examination in order to include or exclude any subjects. Nevertheless the author chose to include this subchapter for informative reason and because the "electromagnetic field" was mentioned in one definition of IOS, described by Druelle DO:

[16] in Osteopathy called "Breath of Life" (correlation made by the author)

> "A change inside of living bony tissue, expressed by change in mechanical resistance (spring); change in vascularization; change in fluid flow; **change in its surrounding/perfusing electro-magnetic field**; and a change in local Primary Respiratory Motion." (Druelle, 2012)

2.7.8 Energetic and mechanical Aspects of mechanical Trauma on Bones

In a book written by Barral DO & Croibier DO called "Trauma - an osteopathic approach" (1999), detailed explanation models of what happens to human tissue in mechanical trauma are given. In medical literature, the term trauma is usually connected with visible tissue damage (i.e. tears, fractures). But what happens if a traumatic force applied to human tissue is not expressed this way? Barral DO & Croibier DO (1999) give simple explanation models based on a basic physical law: The law of conservation of energy (Hobbie & Roth, 2007). This law states that the amount of energy in a system will stay constant throughout time. Therefore this law is stating that no matter how much time goes by, the amount of energy in a certain state of matter will remain the same, hence conserved, no matter how much time has passed. Therefore, physicists have concluded that energy cannot be destroyed. Energy may be able to transform into something different, for instance chemical energy can become kinetic energy, however, nothing can destroy the energy itself (Hobbie & Roth, 2007).

According to the concept of the accumulation of energy (Barral & Croibier, 1999), any body tissue can retain a part of the applied force of collision which has not been expressed in a structural lesion. This concept also explains many cases in which symptoms disappear after a traumatic event and then recur after months or even years. It seems that the traumatic energy is somehow stored within the tissue itself. Barral DO & Croibier DO (1999) use the expression *inheritance* which describes the phenomenon that the body can retain the memory of a traumatic event and that even a asymptomatic trauma within childhood becomes part of an adult patient‘s inheritance.

This inheritance, remnant of a preceding mechanical trauma, could be described as a form of potential energy stored within the traumatized tissue. Potential energy is an energy stored and held in its location until something releases it (Hobbie & Roth, 2007). If a process happens which releases this energy (i.e. an osteopathic therapeutic intervention), the energy is being transformed into another form of energy such as kinetic, thermal or electric energy. Kinetic energy is the energy that an object possesses due to the motion of the object (Hobbie & Roth, 2007).

Barral DO & Croibier DO (1999) mention three important properties of diagnosis of traumatic lesions within living human tissue:

1. **Nothing is forgotten / everything is recorded**: All stresses, whether physical or psychoemotional, are retained in the body‘s memory.
2. **Nothing is isolated**: A trauma to any part of the body can affect any other part.
3. **Everything accumulates**: Any stress to the body is recorded in the tissues, remembered and sometimes even amplified.

These properties show that it can be difficult to find the true nature of a symptom and to find the primary lesion where the chain of compensation has started. According to the authors' experience, many times IOS are primary lesions and lead to compensation patterns with symptoms, usually the joints proximal or peripheral to the site of the IOS.

2.8 Conclusion

Fortunately, the term *intraosseous strain* is well described but not officially defined within osteopathic literature (Brown, 2008). Key parameters to define an IOS are mechanical spring of the bone and its local vitality which is well researched (Mummery, 2008). IOS and vitality have a strong theoretical background but no quantitative proof of existence.

With the given scientific literature it is strongly indicated that thermal imaging is a valid tool even in detecting physiological processes (as breast cancer and osteosarcoma) underneath the human skin and not only of superficial processes on the skin surface.

In order to determine normal skin temperature (which is measured by infrared imaging) of the anterior tibial surface, data from all subjects in the control group of this thesis will be used due to the fact that no previous research has been done on this exact area.

An exploration on the topic of thermoregulation of the human skin has shown that many factors play an important role in controlling core and shell temperature. Neurological pathways regulate this process.

A detailed review of the anatomy has shown that the main blood vessel which nourishes the tibial bone is the anterior tibial artery which also nourishes most parts of the skin of the anterior surface of the lower leg.

Qualitative research has been performed to define how an IOS is described and identified by Osteopaths with local decreased spring and vitality.

These facts increased the authors' curiousness and lead to the main research questions of this thesis: Can thermography detect any significant changes in skin temperatures with IOS and are there any relations between osteopathic manual palpation and thermal mapping of the anterior tibia?

3 CHAPTER THREE: RESEARCH METHODOLOGY

3 CHAPTER THREE: RESEARCH METHODOLOGY

3.1 INTRODUCTION

In this chapter, the complete research methodology will be shown in detail. This quantitative single-blinded observational study used carefully selected subjects who complied to rigorous inclusion and exclusion criteria. In order to indicate the existence of IOS, infrared thermal imaging and osteopathic manual palpation were being compared. All subjects were asked to fill out a questionnaire which clearly indicated division into three groups: Not suitable for this study, control group and case group.

After pre-imaging equilibration in a standardized environment, a standardized thermal image was taken of the anterior tibial skin area of both legs. Because the thermal camera uses a dual picture mode (camera only shows visual picture and not the heat pattern during usage), the author was blinded by not knowing the heat pattern before manual testing.

Subsequently, the subject underwent a standardized osteopathic manual palpation protocol performed by the author.

All questionnaire, thermal and palpation data was collected and put into an Excel sheet which became the data matrix.

3.2 SAMPLE SEARCH

Various methods were used to find appropriate subjects for this study: A publication within the authors' clinic through a leaflet or directly via the author or his employees, and a recruitment campaign through the internet (www.facebook.com). See Appendix 4 for details.

Randomization of the subjects was given because any healthy person without known pathologies of his or her legs, age 22 and above could be part of this experiment. Because this experiment did *not* use a placebo control group for comparing it to another group which receives a therapeutic intervention, randomization was not necessary.

Sample search was performed with detailed information of inclusion and exclusion criteria. During application conversations personally or via the phone, both inclusion and exclusion criteria were already taken into account. This procedure helped to avoid unnecessary drop outs during sample search.

3.3 Inclusion and Exclusion Criteria

3.3.1 Inclusion Criteria

- Inclusion criteria for the case group:
  - Age: 22 years and above (end of tibial growth phase is approximately at the age of 21)
  - Ideally: History of known lower leg trauma and/or repeated mechanical stress
  - Confirmed IOS with osteopathic manual palpation by the examiner
- Inclusion criteria for the control group:
  - Age: 22 years and above

3.3.2 Exclusion criteria

- Exclusion criteria for the case group:
  - Existence of bilateral IOS
  - Known fractures of the lower leg (tibia and/or fibula)
  - Recent superficial or deep injuries (three weeks or earlier) at the site of both tibias due to inability to compare temperatures reliably (active inflammation phase)
  - Any arterial, venous or lymphatic pathology

- Any (sub-)acute skin condition (allergies, eczema, rash, et cetera)

- Exclusion criteria for the control group:
  - Existence of an IOS within any lower leg bone (tibia and/or fibula)
  - Any known superficial or deep injuries (including fractures) of the tibial area younger than 16 weeks
  - Any arterial, venous or lymphatic pathology
  - Any (sub-)acute skin condition (allergies, eczema, rash, et cetera)

3.4 Discussion of Inclusion and Exclusion Criteria

The inclusion criterion "age 22 years and above" is important for this study, because the tibial bone completely ossifies until the 21st year of age (Schünke et al., 2005) and thus physiological activity is markedly decreased within the growth plates, especially the proximal growth plate (Gray, 1918; Schünke et al., 2005). In relation to subjects' age, the author reflected on the possibility that menopause in women might influence skin temperature, but no actual research literature was found on this. And as a search on Pubmed/Medline shows, no literature was found on the influence of osteoporosis on shell and core temperature.

Apley & Solomon (1994) give a rough guide of healing times of tubular bones in the lower limb of healthy adults:

- Callus visible 2-3 weeks
- Union 8-12 weeks
- Consolidation 12-16 weeks

The estimate of 16 weeks for complete healing of a fracture of the tibia and/or fibula - if no delay has happened due to complications - is being used as a general limit for excluding a subject from both case and control group. Unwanted increased physiological activity of the bone and its surrounding tissues are hereby minimized and should help to ensure good infrared image material without any disturbances of unwanted thermal patterns.

The time-limit of three weeks for any recent injury is important to include as an exclusion criterion because it usually takes up to three weeks to finish the inflammation phase of wound healing (Schultz, Ladwig, & Wysocki, 2005). Scar tissue healing takes longer than 3 weeks to heal (Madden & Peacock, 1971), but more on a mechanical load level. Madden & Peacock (1971) claim that full mechanical load bearing capabilities develop within a full year. This mechanical aspect is not very important for this study because the author measures thermal patterns and not mechanical factors of the tissues being examined.

Subjects with fractures of the tibial and/or fibular bone were excluded from the case group due to the fact that this research wanted to test traumatic strains below fracture threshold, thus strains which aren't detectable with common medical imaging systems (X-ray, MRI, CT-Scan). Consolidated fractures within the case group might affect the thermal information of the overlying skin and are being excluded to ensure optimal thermal data. Furthermore, consolidated fractures within the case group might affect osteopathic manual palpation and might falsify intraosseous testing results. Within the control group, 4 subjects showed a fracture within the lower leg, but not the tibia and the fibula (talus, metatarsus 1 and 2, and calcaneus).

Exclusion of any arterial, venous and lymphatic pathologies make sense because any of these physiological states might influence thermal radiation of the skin.

Lastly, the author took the possibility into account that some pharmaceutical medications might influence skin temperature. A Pubmed/Medline search was performed on the following terms:

- Beta blocker (and) temperature

- Aspirin (and) temperature
- NSAID[17] (and) temperature
- Anticoagulant[18] (and) temperature
- Thyroid (and) temperature
- Thyroid (and) hormone (and) temperature

None of the searches above produced any results, even the search for correlation of thyroid hormone intake and body temperature.

Exclusion criteria were precisely defined in order to avoid unnecessary drop outs of subjects. In fact, no drop outs happened during sample acquisition, because if the subject fitted the inclusion criteria and had no IOS determined by osteopathic palpation, the subject was automatically classified into the control group.

3.4.1 Osteoporosis and Rheumatoid Arthritis

Rheumatoid arthritis is a long-term disease that leads to inflammation of the joints and surrounding tissues, thus may affect skin temperature depending on its inflammation state. The questionnaire given prior to examination ruled out any pathologies to the lower leg, but did not specifically asked for rheumatoid arthritis. This detail was not taken into account in the research setup.

Osteoporosis happens when a large amount of the spongy bone tissue breaks down, leaving bigger spaces. This makes the bone more porous and more prone to fracture. The question here is if a subject with osteoporosis has an increased or decreased physiological activity in or around the affected bones and that this might influence shell temperature. A Pubmed/Medline research performed on 2. February 2012 gained no results on this question

[17] NSAID = Non-steroidal anti-inflammatory drug (WebMD, 2008)

[18] anticoagulant = Any agent used to prevent the formation of blood clots (WebMD, 2008)

so this parameter did not have to be included in the questionnaire as a inclusion/exclusion parameter.

3.5 VARIABLES

- **Independent variables:**
  - The osteopathic palpation is understood as a method of clinical examination using gentle pressure of the hands to detect states of spring in human tissue. The variables A/P Spring, Torsion, and vitality are among other variables representing this method.
  - Age of subject
  - Gender of subject
  - Inglehart Index value[19]
  - Weekly frequency of sport activities
  - Number of known mechanical traumata
  - Suspected age of mechanical traumata/IOS
- **Dependent variables:**
  - The IOS of the tibia is measured by using a thermal imaging camera. Thus the **skin temperature** of all four tibia groups (A, B, C and D) is measured separately for a predefined zone. A thermal imaging camera is processing the infrared radiation as visible light and renders the image in colors which define temperature values. The temperature is measured in degree Celsius and sorted by colors. In our investigation, exclusively the shell temperature is measured and used for analysis.

[19] Details on Inglehart Index value: see Chapter 3.9.3

3.6 Measuring Instruments and supportive Equipment

3.6.1 Thermographic Camera

In this thesis, the author uses a thermographic device produced and sold by *Trotec* (www.trotec.de), details shown below:

Figure 6. Trotec EC 060 Infrared Camera (Trotec, 2011)

In order to process the thermal images taken, the Trotec EC 060 comes with a computer software called *IC-Report Standard*. Within this software, the author can do the following:

- Open and view thermal images taken by Trotec EC 060
- Show temperatures (exact, maximum, minimum and average in degree celcius):
    - At any location
    - Within in a defined area
    - Along a defined line

The Trotec EC 060 has been used in medical research before (Wolter & Kieselbach, 2011) and was found to be accurate for measuring living tissue temperature. This study measured skin temperature of the fingers before and after spinal cord stimulation with an electrode in subjects with Raynaud‘s Syndrome on one single patient. Raynaud‘s Syndrome is known to be a vasospastic condition affecting primarily the distal resistance vessels of extremities (Wolter & Kieselbach, 2011). Next to thermal data, clinical effects as pain in both hands were observed. Results were that the therapeutic intervention of spinal cord stimulation effectively increased peripheral blood flow (vasodilation) and decreased subjective pain in both hands. Important to note is that the thermal readings significantly correlated negatively with pain levels. Thus increased peripheral blood flow (vasodilation induced by spinal cord stimulation) led to increased heat readings of the skin surface of the fingers. The article (Wolter & Kieselbach, 2011) did not mention if they used international standards of thermal imaging and did not describe exact examination procedures and parameters such as room temperature, air humidity and examination room design. This fact might imply that absolute temperature readings might not be very exact, but the temperature difference (before and after intervention) should have been exact enough to provide valid statistical numbers. In 2012, Wolter & Kieselbach repeated this experiment with 23 patients and successfully used the Trotec EC060 again for assessment.

The International Academy of Clinical Thermology (Thermology, 2002) doesn't recommend specific infrared camera equipment, it gives a list of minimum specifications an infrared device should have:

- Detector response with the spectral bandwidth encompassing 8-10 micron region
- Repeatability and precision of 0.1 °C detection of temperature difference
- Accuracy of +/- 2% or less
- Significantly variable contrast (level) settings
- A maximum scanning time of 4 seconds or less with real-time capture
- High-resolution image display for interpretation
- Ability to archive captured images
- Image processing and data capturing software

All above mentioned requirements are fulfilled with the Trotec EC 060. Finally, the Trotec EC 060 is calibrated to ensure maximum accuracy. See Appendix 9 for detailed technical information on this camera device and the letter of conformity and calibration from the Trotec company.

3.6.2 MANUAL PALPATION AS AN IDENTIFICATION AND CLASSIFICATION TOOL FOR INTRAOSSEOUS STRAINS

The Swiss International College of Osteopathy teaches the existence of intraosseous lesions and defines what they feel like on a palpatory level, but little information is given for exact testing and locating. Instead, Chauffour DO & Prat DO (2002) and Heller DC (2005) talk about testing the spring or stiffness of the bone in all spatial dimensions and give precise instructions how to locate and define the IOS in all three dimensions. The author used a simplified testing protocol (see Appendix 3) using local/regional spring tests with local listening of tissue vitality (as a consequence of the qualitative thesis from Brown DOMP (2008) and lectures from Druelle DO (2011a)).

3.7 SUPPORTIVE EQUIPMENT USED

Next to the thermal camera, the following supportive equipment was used:

- Gymna Osteoflex treatment table;
- Digital temperature and air humidity meter;
- Small hard pillow used under the knees for examination;
- A terrycloth towel used to cover legs.

3.8 EXPERIMENT SETUP

International standards defined by Diadikes & Bronzino (2008) and Ring et al. (2004) were used to ensure proper infrared imaging:

- **Examination room type:**
  - Minimum size of 2x4 meters. Actual examination room size was 16 square meters.
- **Room climate:**
  - Relative humidity: It is recommended to have a dry environment to avoid sweating of the skin, thus approximately 20-55%.
  - Room temperature: To avoid vasoconstriction of the skin due to cold temperatures and to also avoid sweating of the skin due to hot temperatures, a 20-25 ˚C ambient room temperature was used. This was no problem in this research project, because the planned examination room had floor heating with a precise thermostat.
  - Air conditioning: No air conditioning equipment is recommended and overall low air speed within the examination room. The actual examination room had no air conditioner and its door and windows were airtight.
- **Position for imaging:** A standard view of the tibias was used, see Figure below. The complete anterior view of the tibias was photographed, including part of the feet and knees. Distance between toes of the subject and mid-foot of the tripod was 240 cm and the height of the midpoint of the camera lens from the ground was 51 centimeters.

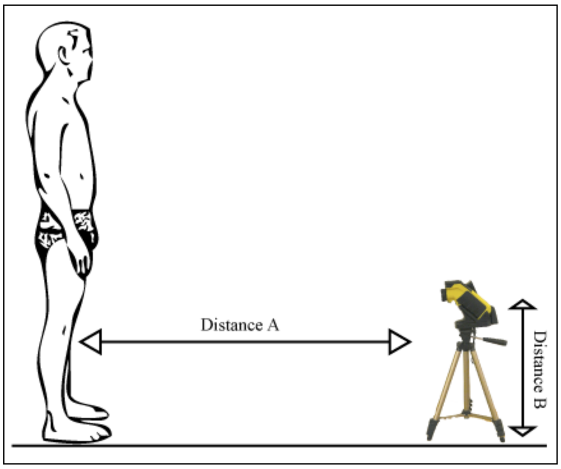

Figure: 7. Distance A between tibia and IR Camera: 240 centimeters. Distance B between ground and midpoint of camera lens: 51 centimeters.

3.9 EXPERIMENTATION PROCEDURE AND DATA COLLECTION METHOD

3.9.1 INFORMATION GIVEN TO TEST SUBJECTS BEFORE EXAMINATION

Before the infrared picture was taken, the subject had to sign a form of consent (see Appendix 5) at least 24 hours before examination and an information letter was handed out which informed about "things to avoid" before infrared examination. This letter stated requests by the author to ensure that the measured temperature during examination would be as precise as possible (see Appendix 5):

- No usage of cosmetics (skin lotions, ointments et cetera) on the day of examination
- No alcohol intake on the day of examination
- No smoking approximately 1 hour before examination
- No large meals and excessive tea/coffee intake on the day of the examination
- Avoid tight fitted clothing on the day of examination
- Avoid physical exertion on the day of the examination
- Avoid any manual/physical therapy on the day of the examination

- Drugs affecting the cardiovascular system (blood pressure medication et cetera) should be reported to the examiner

3.9.2 Signing the Form of Consent

Each subject had to sign a specific form of consent (see Appendix 5) before he or she was able to participate in the research. The subject hereby signed a paper which explained in detail what was going to happen during examination, that he or she could withdraw from this study anytime and that his or her identity would be kept anonymous at any time.

3.9.3 Filling out the Questionnaire

Each subject had to fill out a short questionnaire (see Appendix 8) before examination. It was given in an envelope (blinded) and was not shown to the examiner until after manual osteopathic examination.

It was decided (with the help of the Statistician Hüttenmoser Oliva) that if a subject has had multiple accidents, the most recent accident was taken into the data matrix.

As advised by Hüttenmoser Oliva (2011), a third variable control method should be used to exclude spurious correlation results. A spurious correlation is a correlation between two variables that does not result from any direct relation between them, or explained more in detail:

> "A confounding variable, also known as a third variable or a mediator variable, can adversely affect the relation between the independent variable and dependent variable. This may cause the researcher to analyze the results incorrectly. The results may show a false correlation between the dependent and independent variables, leading to an incorrect rejection of the null hypothesis." (Bauer, 2009; Shuttleworth, 2008, p.238)

In order to control spurious correlations, each subject will be asked to answer two additional questions which will collect data for a third variable, the Inglehart Index:

> "The Inglehart index of post-materialism is measured by people's priority for low inflation and order. We use regression analysis to correct national averages of the Inglehart index for the effects of observed inflation and (violent) crime rates for selected European, Asian and South American countries. Low inflation and low crime rates significantly increase the Inglehart index, but we also observe a trend towards post-materialistic values. This trend cannot be explained by economic growth alone." (Oliver & Richard, 2003, p.189)

The text used for creating the form to determine the Inglehart-Index of each subject is being taken from Bortz & Döring (2006).

Table: 5. QUESTIONS TO DETERMINE THE INGLEHART INDEX

If you had to choose among the following things, which are the **two** that seem the most desirable to you?
A: Maintaining order in the nation.
B: Giving people more say in important political decisions.
C: Fighting rising prices.
D: Protecting freedom of speech
Which one of the mentioned things above do you classify as MOST IMPORTANT: Please mark letter A, B, C or D.
Which one of the mentioned things above do you classify as SECOND IMPORTANT: Please mark letter A, B, C or D.

3.9.4 PRE-IMAGING EQUILIBRATION

Upon arrival at the examination, the subject was given information about the examination procedure, instructed to remove appropriate clothing (in this study: pants, both socks or any stocking which could cover the foot and the tibia), and asked to sit or rest in the examination room for a fixed time of 15 minutes.

3.9.4 CAPTURING THERMAL IMAGES

First, there was a thermal image taken of the anterior side of both tibias with the Trotec EC 060 camera. It was mounted on a commercially available camera tripod (EF digital star 700, sold by hama). The construct camera-tripod looked like the following:

Figure: 8. Infrared camera and its tripod

The camera was positioned in a standardized distance to each subject (see chapter 3.8., figure 7). This setup ensured identical distance and picture quality.

The examiner did not see the heat pattern of the infrared image, because the Trotec EC 060 has a double-image mode where the examiner only sees a normal picture and at the same time the camera records an infrared image without showing it. Images being taken by an independent assistant and this "dual-image" mode ensured that the examiner was single-blinded (author did not know what the temperature readings looked like) before osteopathic palpation examination.

The reason why the whole anterior side (superior border: inferior margin of the patella, inferior border: horizontal mid-line between lateral and medial malleolus) of the tibia was taken to calculate the average temperature and not only the exact location of the intraosseous lesion is that thermal imaging quantitatively shows current state of skin blood flow (Diadikes & Bronzino, 2008; Plaugher, 1992; Ring, unknown; Ring & Ammer, 2000; Ring et al., 2004) and the tibia is mainly nourished by the anterior tibial artery (see chapter 2.2.2.1 for details) which also vascularizes the anterior skin surface of the lower leg (Schünke et al., 2005).

The logical theory to this anatomical fact is that an IOS might alter skin temperature globally at the anterior surface of the lower leg and not only its local spot. Standing position of the subject was chosen to ensure exact distance between the camera and the subject. According to Roy, Boucher & Comtois (2010) there are no differences between prone and standing temperature measurements if symptom-free subjects are given 8 minutes to acclimate (in this study, 15 minutes are being used) before performing thermal imaging.

For illustration purpose, an anonymous infrared picture of one of the case group subjects is shown below:

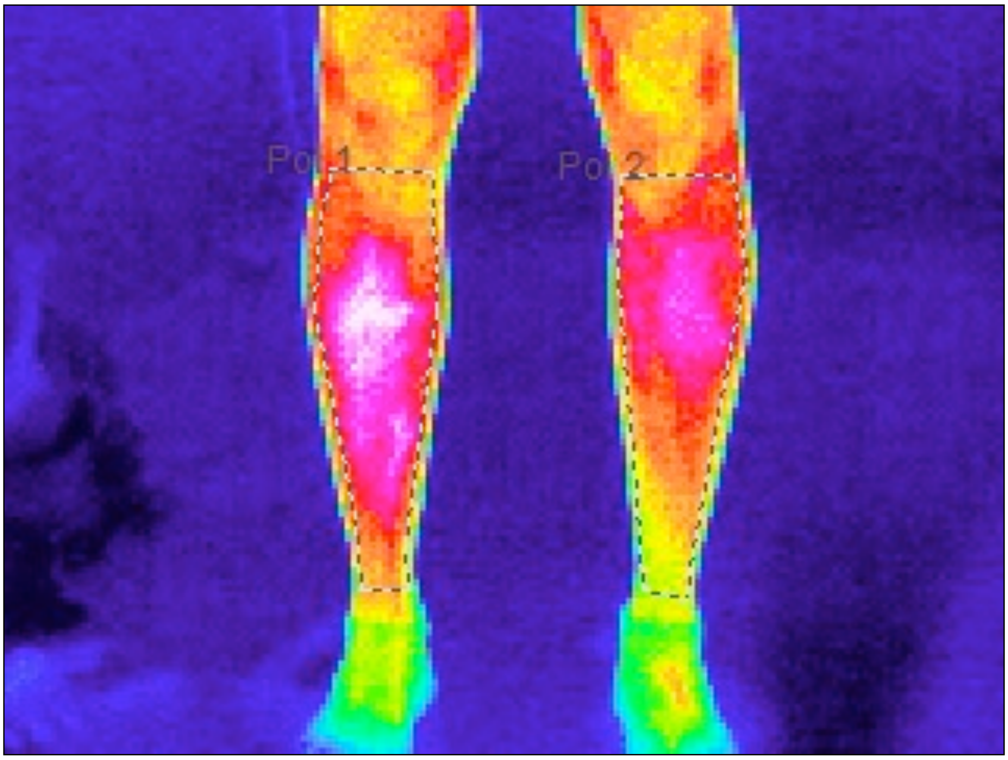

Figure: 9. Anterior view of an infrared picture taken within this research (left tibia has an IOS)

Figure 9 should be read like the following: Black is the coldest temperature, then blue, then green, then yellow, then orange and the white as the warmest color. Each color defines an exact temperature value defined by the thermographic software used.

3.9.5 PERFORMING THE OSTEOPATHIC MANUAL EXAMINATION

After having thermal images taken of both tibias in one image and annotation of the infrared image number on the examination form by the assistant, palpation tests were performed by the examiner and the result was noted in an examination form. The palpation protocol was validated by Tara Drew DO, a teacher of CCO/CEO/SICO. Detailed description of the used palpation tests are found in Appendix 3.

Table: 6. FINDINGS NOTED WITHIN MANUAL EXAMINATION

Spring tests:	Vitality listening:
0 (normal)	0 (normal)
1 (slightly hard)	1 (slightly low)
2 (hard)	2 (low)
3 (very hard)	3 (none)

78% of the Osteopaths from all over the world interviewed by Mummery (2008) use descriptive palpation, 40% used visual observation of vitality, 34% use palpation results vitality or No vitality, 34% use patient's verbal description of their own vitality and 19% use a number scale from 1 to 10. The author chose the scale 0/1/2/3 to be able to convert the received palpatory sensations form the examination into statistically useful values.

3.10 BIAS

3.10.1 SAMPLE BIAS

- Subjects were acquired within the authors clinic, via the Web (www.facebook.com; a social network) and via personal invitation. This results in a sample group which does not represent the general population. The subjects within the control group were chosen by the author, he tried to attain a normal distribution of age, sex and other parameters. The subjects within the case group were acquired directly by publishing inclusion/exclusion parameters.

3.10.2 METHODOLOGY BIAS

- All subjects had to avoid a list of activities and things on the day of the examination (see chapter 3.3.1). The examiner could not control if all recommendations had been followed by the subjects or not and had to trust that they tell the truth.
- Not all influencing parameters of the shell temperature could be eliminated (i.e. electromagnetic field distortions, sympathetic and somatic neurological influence of spinal segments, traumatic parameters, et cetera) by the examiner. Certain parameters could affect the skin temperature of the anterior tibia.
- The examiner did not know the result of the questionnaire and the infrared image taken (questionnaire and thermal images were blinded) before manual examination. These procedures ensured proper blinding before manual palpation.

- Dividing all subjects into case and control group solely depended on the palpation capabilities of the examiner. So if the examiner did not palpate well, subjects might have gotten categorized into the wrong group - this is one of the strongest weakness of this study.
- The used camera type (Trotec EC 060) has only been used within one medical study before (Wolter & Kieselbach, 2011), although all standard requirements were given and strict image taking standardization was used to ensure similar infrared images.
- Definition of the area of the anterior skin surface of the lower leg within the software used to read out temperature values. This area was drawn manually on the computer-screen with computer-mouse movements (see Figure 9), thus 100 percent exact definition of all lines which form this area was not possible.
- Scars of the skin along the anterior side of the lower leg were not being taken into consideration. The examiner was not perfectly single-blinded because he could conclude any previous trauma by detecting existing scars. The author considered the possibility to exclude any subject with scars along the lower leg(s) but decided *not* to do this. Scars can be an indication of any trauma, even "just" a small cut years ago. This exclusion criteria would decrease massively the possibility to find enough suitable subjects for the case group.

3.10.3 Bias Control Methods

It was not possible to control whether the subjects really avoided the activities mentioned in the information letter given prior to examination. The examiner had to trust the information given by each subject. The examiner was single-blinded before the manual osteopathic palpation procedure. The subjects were told not to pass on information in regards to their symptoms and problems (if there are any) until after the manual osteopathic palpation procedure.

3.11 Ethical Considerations Concerning Privacy

This research was performed in such a way that anonymity of each subject was given at all times. After data collection, all examination protocols were kept anonymous.

Each infrared image was labeled with the number of the corresponding subject. Making the images unidentifiable was not necessary because thermal images have a low resolution in thermal coloring ("rainbow coloring") and can not be matched to a person.

All research data and thermal images were stored securely by the author and a copy was offered to each subject if requested.

3.12 Conclusion

After performing standardized procedures of taking thermal images and performing manual osteopathic palpation, the data was revealed to the author. All inclusion and exclusion criteria were taken into consideration and all samples were divided into three groups: Not suitable group, control group and case group. The acquired data was put into a data matrix and analyzed by a statistician, Cornelia Hüttenmoser Oliva.

4 CHAPTER FOUR: DATA ANALYSIS AND INTERPRETATION OF RESULTS

4 CHAPTER FOUR: DATA ANALYSIS AND INTERPRETATION OF RESULTS

4.1 INTRODUCTION

During the time between spring 2012 and late autumn 2012, the author recruited patients from his therapy clinic and other subjects to participate in his study. Investigating the previously mentioned hypotheses, a structured questionnaire has been developed. Forty-three structured interviews were conducted, 20 in the case group and 23 in the control group.

First, all data was collected (questionnaire data, thermal image data in degree Celsius and palpation data) and put into a data matrix within a Numbers (Excel Version on Macintosh Computers) sheet. This data matrix was entered into a statistics software called SPSS from IBM (Version 19 for Windows). After labeling the variables and setting the values for each variable, the data matrix was now at one's disposal in order to carry out the data analysis.

Next to descriptive analysis, correlation analysis, analysis of variance and post-hoc tests were used.

4.2 HYPOTHESES

1. The **mean average skin temperature (MAST)** of the intraosseous-affected side is lower than
   a) **MAST** of the contralateral (healthy) side of the case (intraosseous) group.
   b) **MAST** (baseline temperature) of the control group.
2. The **MAST difference** between the intraosseous-affected side and the **MAST difference** of the contralateral (healthy) side in the case group will be significantly higher than **MAST difference** between left and the right side within the control group.

3. There is a *negative* significant correlation between **rigidity (A/P Spring)** of the intraosseous-affected tibia and its average skin temperature.
4. There is a *positive* significant correlation between the **expression of vitality** of the of the intraosseous-affected tibia and its average skin temperature.
5. There is *no* significant correlation between the **accident/injury/operation (AIO)** age of an IOS and the average skin temperature of the intraosseous-affected tibia.

4.3 STATISTICAL METHODS

4.3.1 *DESCRIPTIVE STATISTICS*

The descriptive analysis was carried out not only to prove the quality of the collected data, but also to give a description of the data and a short overview of the main variables. Besides proving the data quality as already mentioned, the possibility of outliers[20] shall be clarified.

4.3.2 *CORRELATIONS*

The analysis of the correlations between variables is understood as a preliminary stage of causal analysis. In the analytic strategy, we wanted to clarify the relationships among the main variables. According to the measurement scale of the variables (ordinal scale) the presented correlation coefficient is Kendall tau-b. Correlations up to 0.02 are interpreted as weak, up to 0.04 as medium and up to 0.06 as strong correlations. The sign of the correlation coefficient tells us whether there is a positive or negative correlation. Correlation coefficients above 0.06 will be understood as an indication for autocorrelation. SPSS simultaneously shows the significance of correlation. If a correlation on the 1% level is significant, the correlation coefficient tau-b will be marked with two stars (** $p < 0.01$), and respectively on

[20] In statistics, an outlier is an observation that is numerically distant from the rest of the data.

the 5% level the correlation coefficient will be marked with one star (*$p < 0.05$) (Huettenmoser Oliva, 2012).

4.3.3 *ANALYSIS OF VARIANCE*

To test our hypotheses, the specified measurement models were included in general linear models using analysis of variance. The results of the analysis of variance tell us whether three or more means are significantly different or not. In other words, analysis of variance tests the null hypothesis that all group means are equal. The procedure yields to the F-ratio comparing the amount of systematic variance versus the unsystematic variance. The value of F is the share of the model relative to its error. The Levene Test was applied testing the homogeneity of the variances (homoscedastic data versus heteroscedastic data). Finally, robust test[21] statistics were applied (Welch test, Brown-Forsythe test).

4.3.4 *POST HOC TESTS*

Furthermore, a pairwise comparison was designed to compare all different combinations of the mean average skin temperature for all four groups A, B, C and D. This comparison of all combinations was carried out with the post hoc test. As we had an unbalanced design, a different group size and a different population variance, it was suggested to apply the Dunnett test controlling for the Type I Error (Huettenmoser Oliva, 2012). We also applied the most powerful test, the Games-Howell test, which can be liberal with small sample sizes, but still is accurate when sample sizes are unequal.

[21] Robust statistics seeks to provide methods that emulate popular statistical methods, but which are not affected by outliers from model assumptions.

4.4 DATA SET

Descriptive statistics were used to compare two groups of data of a minimum of 20 samples. In order to draw statistically significant data, Huettenmoser Oliva (2011), advised to achieve a sample size of 40 subjects with each two tibias (N=80). From a methodological standpoint, a sample size as large as 30 or more has a normal distribution of sample mean score (Huettenmoser Oliva, 2011). For this research, 86 tibias subjects were tested (N=86), 23 subjects (each with two healthy tibias) within the control group and 20 subjects (each with one affected tibia and one healthy tibia) within the case group with each one tibia with a positive palpatory finding of an IOS.

4.4.1 DESCRIPTIVE STATISTICS OF SAMPLE

According to the hypothesis, the sample was divided into a case group (46.5 %) and into a control group (53.5 %) based on palpatory assessment of IOS.

Age. As shown in Table 6 (Appendix 10), 43 subjects participated in this study. 46.5% were women and 53.5% men. The average age was 33.4 years. The youngest person was 22 years old and the oldest person was 60 years old. 46.5 % belonged to the case group and 53.5 % to the control group.

Gender. 46.5 % were women and 53.5 % were men.

Complaints. Complaints (foot, knee, lower leg) were reported from 41.9 % of all subjects. 55.8 % reported to have had a previous AIO (accident/injury/operation) which happened 2.4 years ago on average. Out of the subjects with a previous accident, injury or operation, 46.5% claimed that the mentioned event is not responsible for the presented symptoms in the lower leg area. In the case group, 75% reported complaints in the lower leg. In the control group, only 15% reported complaints.

Sports activities. 18.6 % of all subjects reported engaging in a sport activity twice a week and 16.3 % reported no sport activity at all. Subjects of the case group averagely performed 2.53 times a week a sport activity. In the control group, they performed 1.65 times per week a sport activity by average. This distribution makes sense because the author specifically acquired active people with a history of accidents in this research for finding IOS of the tibia.

Inglehart Index. Most of the subjects reported having a post materialistic attitude (46.5 %) and only 14 % showed a materialistic attitude. This statistical parameter was used to exclude spurious correlation result and was taken into consideration during statistical analysis.

Palpation tests. Within the legs which had a positive finding for an IOS,

- the **A/P Spring test** was palpated "normal" in 53.5% of all subjects (these were put into the control group), 20.9% "slightly hard", 18.6% "hard" and only 7% "very hard".
- the **Torsion test** was palpated "normal" in 55.8% (this means one subject in the case group had a postive torsion test), 30.2% "slightly hard", 11.6% "hard" and only 2.3% "very hard".
- the **Vitality test** was palpated "normal" in 53.5% of all subjects (these were put into the control group), 23.3% "slightly low", 18.6% "low" and only 4.7% "none".

Accident/injury/operation (AIO). Accordingly 46.5 % of the persons had no AIO side. 23.3 % persons did report an AIO on the right side and 25.6 % reported an AIO on the left side. 4.7 % of the persons did report an AIO on both sides.

Accident/injury/operation (AIO) age. The most frequent mentioned AIO age lay between 1-2 years. 9.3 % of the partcipants said that the AIO was more than 11 years ago. The same amount of participants said that the AIO was already 3-5 years ago and again 9.3 % said that the AIO was 1-4 months ago. 7% of the participants said that the AIO was 5-12 months ago and also 7 % said the AIO was 6-10 years ago. 46.5 % of the participants did not make a statement to the AIO age. In the case group, 90% reported on or more AIO's. In the control group, 26% reported one or more AIO's.

In order to avoid confusion, all measured tibial skin temperatures were grouped and named as A, B, C and D. See below the exact definition of each group:

A. Intraosseous affected leg within the case group
B. Non-affected ("healthy") leg within the case group
C. One leg of the control group
D. Other leg of the control group

Table 7 (Appendix 10) displays the descriptive statistics that is the range, mean, standard deviation (SD) and the percentage (%) of the central variables:

Temperature. The mean of the skin temperature of the tibia group A is 29.36 °C and the standard deviation was .91°C. The mean of the skin temperature of the tibia group B was slightly higher 29.96 °C and showed a standard deviation of 0.78°C. The mean of the baseline temperature was 30.36 °C and its standard deviation was 0.82°C. The baseline temperature was calculated with the temperature readings of the tibia group C and D.

Table 7 (Appendix 10) summarizes the skin temperatures of the intraosseous affected tibias (A) and unaffected tibias (B) for the case and control group (C & D) showing the mean and standard deviation (SD). Furthermore Table 7 (Appendix 10) shows that the mean of the average temperature of the intraosseous affected legs (A) is lower than the baseline temperature (calculated from the skin temperature of both tibias C and D of the control group).

In a next step, the average temperature of all four tibia groups (A, B, C and D) was summarized for the case and the control group. This is displayed with a boxplot and is shown in figure 10 below. **The highest average temperature observed for the tibia C was (*median* = 30.91 °C). The lowest average temperature observed for the tibia A was (*median* = 29.13 °C)**. The whiskers of the boxplots show the minimum and the maximum for each tibia respectively.

Figure 10 reports that the average skin temperature, for all four tibias A, B, C and D measured separately, of the intraosseous-affected side is lower than the contralateral (healthy) side of the intraosseous group and also lower than the control group (baseline temperature).

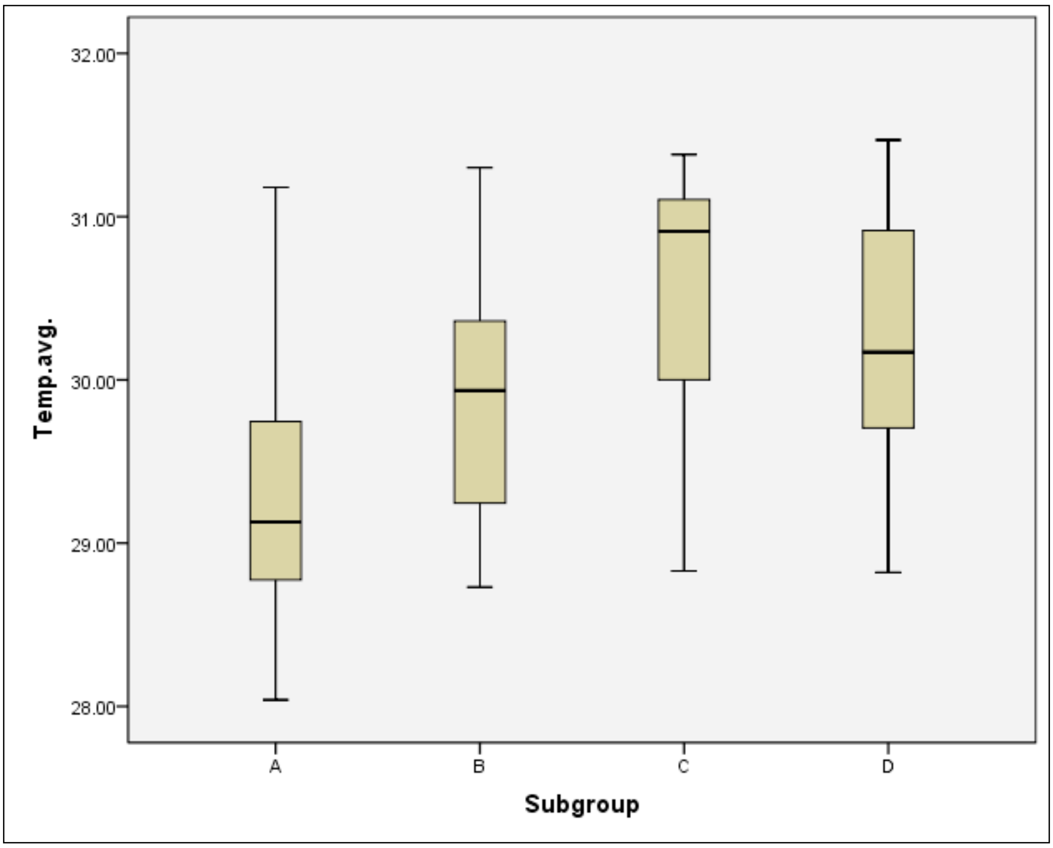

Figure: 10. Boxplot for average temperature of anterior tibia A, B, C, and D

The average temperature for the case group and the control group is summarized and shown in figure 11 below. **The median of the average temperature for the tibia group A & B (29.48 °C, case group) is 1.15 °C lower than the median of the average temperature for the tibia group C& D (30.63 °C, control group).**

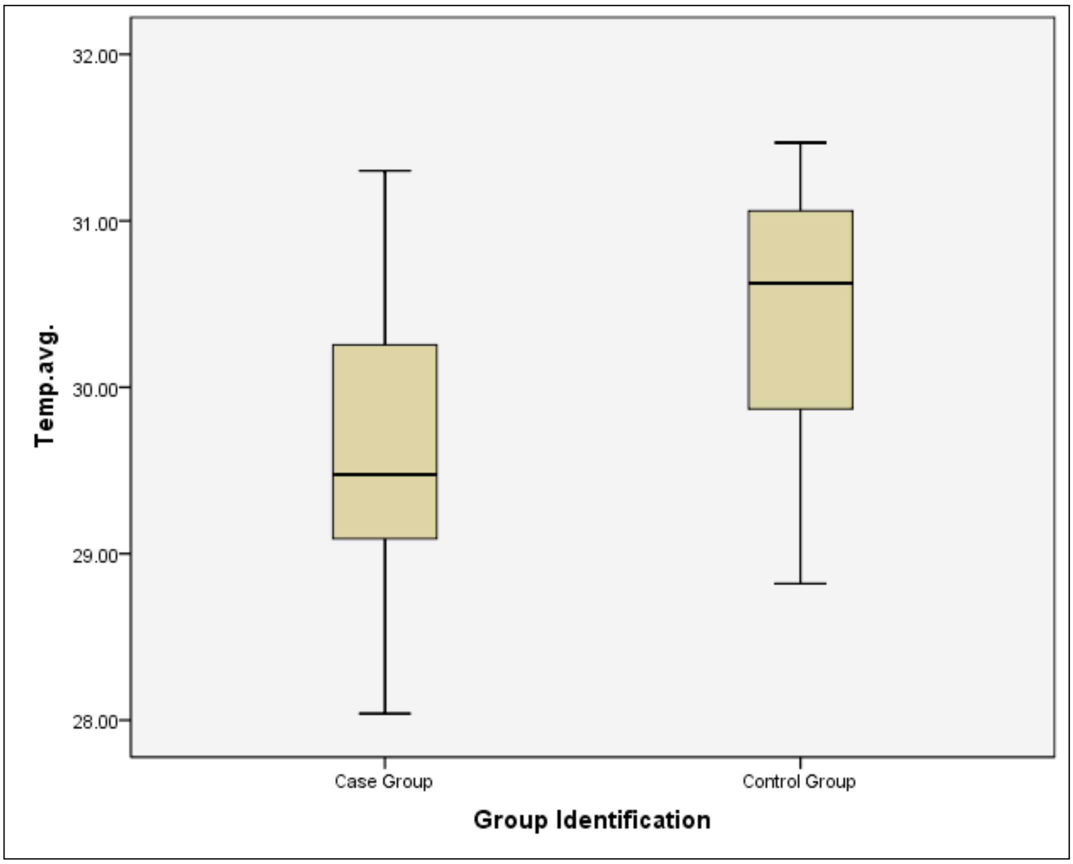

Figure: 11. Boxplot for average temperature for all anterior tibia of the case and control group

4.4.2 CORRELATIVE STATISTICS OF SAMPLE

The correlations between A/P Spring, Vitality, the AIO ages, and the average temperature of tibia A are shown in Table 9 (Appendix 10). **Hypothesis 3** suggests a negative correlation between rigidity (A/P Spring) of the tibia group A and its average skin temperature. The rigidity is represented by A/P Spring. There is a negative, medium to low significant correlation between the A/P Spring and the average skin temperature of the intraosseous-affected side (tibia A) in the case group (τ_b = -.394, p < .05).

Further observation showed that there is a negative and low to none significant correlation between the Torsion and the average skin temperature of the intraosseous-affected side (tibia A) in the case group (τ_b = -.295, n.s.).

On the basis of these correlations, we gain some indication of a negative relationship between the rigidity of the tibia and its average skin temperature of the case group. Some evidence is therefore given for hypothesis 3.

Hypothesis 4 further suggests that there is a positive correlation between the expression of the tibia‘s group A vitality and its average skin temperature. As shown in table 9, there is no significant correlation between the vitality and the average skin temperature (τ_b = -.344, n.s.). On the basis of this correlation analysis, there is no proof anticipated for a relationship between vitality and the average skin temperature within the tibia group A.

Finally, **hypothesis 5** suggests that there is no correlation between the AIO age and the average skin temperature in the tibia A group. In fact, and as it is shown in Table 9 (Appendix 10), there is no significant correlation between the AIO age and the average skin temperature in the tibia A group (τ_b = .079, n.s.). As presumed, the AIO age is independent of the average skin temperature of the intraosseous-affected side in the case group.

4.4.3 Analysis of Variance

To test the hypotheses, the here specified measurement models were included in the general linear models using analysis of variance. The result of the analysis of variance tells us, as already mentioned, whether three or more means are the same. In other words, analysis of variance tests the null hypothesis that all group means are equal. The procedure yields to the F-ratio comparing the amount of systematic variance versus the unsystematic variance. The value of F is the share of the model to its error.

The pairwise comparison was designed in order to compare all different combinations of the average temperature for the tibias A, B, C, and D of the case and the control group. This was carried out with the post hoc test. As we have an unbalanced design, meaning that the group size is different (case group = 40 observations and control group = 46 observations), and therefore different population variances, Dunnett-T3 and Games-Howell tests were applied. Appendix 10 shows the corresponding tables. Additionally, Levene test is applied and robust test statistics (Welch F, Brown-Forsythe F) testing whether the variances are significantly different. This is shown in Table 12 (Appendix 10).

Hypothesis 1a suggests that the MAST[22] (A) < MAST (B). As shown in the statistical evaluation there is no significant difference between the average temperature for tibia group A and the temperature for tibia group B for the case group (Dunnett-T3 exact $p = .095$). Hypothesis 1a cannot be confirmed.

Hypothesis 1b suggests that the MAST (A) < MAST (C&D). As shown in the statistical evaluation there is a significant difference between the average temperature for tibia group A and the average temperature for the tibia groups C & D (Dunnett-T3 exact $p < .001$). This confirms hypothesis 1b that there is a strong and significant difference of the average temperature between the tibias A and (C & D).

Hypothesis 2 suggests that the MAST difference between the intraosseous-affected tibia group A and the contralateral (healthy) side within the case group will be significantly higher than MAST difference between left and the right side within the control group (C&D). Hypothesis 2 is summarized as follows: MAST (B:A) > MAST (C:D). As shown in table 10 (Appendix 10), there is a significant difference of the average temperature between the case group (B:A), and the control group (C:D) ($F_{(1,41)} = 14.648$, $p < .001$). The homogeneity of variances is given. Hypothesis 2 is confirmed.

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[22] MAST = Mean Average Skin Temperature

5 CHAPTER FIVE: DISCUSSION OF RESULTS

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5.1 INTRODUCTION

In this chapter, the statistical results of this research are discussed. Because this thesis suggests six hypotheses, it is important to outline each result. Accordingly, certain hypotheses seem to have a clear outcome and other hypotheses need discussion in order to try to interpret their statistical outcome. Half of the given hypotheses are confirmed, the other half are rejected. These results create a partially positive result of this research project - mainly the fact that the data seem to indicate that IOS can be located with a quantitative measurement tool (thermography), thus the existence of IOS seem to be quantitatively confirmed - and not only by manual palpation.

5.2 THE HYPOTHESES AND THEIR RESULTS

To answer the research question, we shall outline our hypotheses as follows:

5.2.1 HYPOTHESES 1A AND 1B

The **mean average skin temperature (MAST)** of the intraosseous-affected side is lower than the

a) **MAST** of the contralateral (healthy) side of the case (intraosseous) group

Statistics showed that the mean average skin temperature (MAST) of the intraosseous-affected tibia group A is not significantly different ($p = .095$) to the contralateral tibia group B.

The **mean average skin temperature (MAST)** of the intraosseous-affected side is lower than the

b) **MAST** (baseline temperature) of the control group.

On the other hand, the MAST of the intraosseous-affected tibia group A has a strong significant difference ($p < 0.001$) to the MAST of the legs from the control group (baseline temperature, C&D). **Thus hypothesis 1a is unconfirmed, hypothesis 1b is confirmed.**

This result confirms the authors' theory that an IOS within a bone regionally decreases physiological activity and may negatively affect regional blood flow.

This acquired knowledge leads to an assumption that there might be a neurophysiological connection between the two legs of one person. According to Pelletier DO et al. (2006), the four interosseous membranes (lower leg left and right, forearm left and right) have a intimate neurophysiological link. Pelletier DO et al. (2006) claim that it is possible to positively influence a lower leg within a cast indirectly while treating the contralateral side.

This could lead to the assumption that the affected lower leg (A) influences the other leg (B) by affecting its physiological activity and/or its regional blood flow. Next to this, one could assume that if one leg is affected by an IOS, the leg would try to avoid weight bearing and thus the contralateral side might compensate. This would lead to an "overuse" of the contralateral (unaffected) leg within the subject and might affect regional temperatures.

5.2.2 HYPOTHESIS 2

> The MAST difference between the intraosseous-affected side and the MAST difference of the contralateral (healthy) side in the case group will be significantly higher than MAST difference between left and the right side within the control group.

Results showed that **hypothesis 2 is confirmed** because there is a higher temperature difference ($p < 0.001$) between the legs within the case group than within the control group. This result again contributes to an emerging theory that an IOS within a bone regionally decreases physiological activity. This hypothesis only empowers hypothesis 1b and thus strengthens the authors' assumption that an IOS lowers local and regional skin temperature.

5.2.3 HYPOTHESIS 3

> There is a negative significant correlation between rigidity (A/P Spring) of the of the intraosseous-affected tibia and its average skin temperature.

Hypothesis 3 wants to show that increased rigidity of a bone's IOS leads to a decreased regional skin temperature and thus indicating a negative effect on regional physiological activity. Unfortunately there is only a low negative significant correlation ($p < 0.05$). This means that **hypothesis 3 is confirmed, but with a low significance**. Thus the presented data shows a tendency which needs to be confirmed by additional research.

The author expected this result with a higher significant outcome, but maybe the limited sample size and the difficulty finding really hard IOS within the time frame of this research led to this weak result.

5.2.4 HYPOTHESIS 4

> There is a positive significant correlation between the expression of vitality of the of the intraosseous-affected tibia and its average skin temperature.

Statistical assessment of the sample group showed that **there is no significant positive correlation between vitality and average skin temperature of the intraosseous-affected tibias (A)**. Because vitality is defined as "the expression of life force in a body" (Mummery, 2008), one could think that increased expression of life force might lead to increased physiological activity within the tissue and thus again might increase local temperature. Another question to follow upon would be if expression of vitality is being (also) expressed by increased infrared radiation which one can measure as temperature values.

Druelle DO (2012) distinctly mentioned that vitality is the closest parameter to explain or define the nature of an IOS.

5.2.5 HYPOTHESIS 5

> There is no significant correlation between the accident/injury/operation (AIO) age of an IOS and the average skin temperature of the intraosseous-affected tibia.

Suspected age of an IOS and its measured average skin temperature have no significant correlation. This means that the data used in this study shows that the **age of an intraosseous strain has no influence on its temperature values**. This statistical indication contradicts the empirical experience of the author and the teachings of Philippe Druelle DO as already stated in Chapter 2. Druelle DO (2012) claims, that by his practical experience, a fresh or young IOS tends to create a local increase in perceived skin temperature, and an old IOS tends to create a local decrease in perceived skin temperature.

This result does not allow this study to make any strong statements about this correlation except that further research may be helpful.

According to the authors' experience, one of the few palpatory features which indicate the approximate age of an IOS is the speed of the release process while treating it; the older an IOS is, the slower it releases during treatment. Furthermore it might be interesting to mention that this result might confirm the theory that an IOS cannot dissolve by itself in time (see subchapter 2.2).

5.3 CONCLUSION

In short, it is statistically indicated **with strong significance** that

- the MAST of the intraosseous-affected tibia (A) has a difference to the MAST of the legs from the control group (hypothesis 1b)

- there is a higher temperature difference between the legs within the case group than within the control group (hypothesis 2)

that it is statistically indicated **with low significance** that

- there is a negative correlation between rigidity of a bone‘s IOS leads and regional skin temperature (hypothesis 3)

and that it is **not statistically indicated** that

- the MAST of the intraosseous-affected tibia (A) is different to the contralateral leg (B) within the case group (hypothesis 1a)
- there is a positive correlation between vitality and average skin temperature of the intraosseous-affected tibias (A) (hypothesis 4)
- there is a negative correlation between suspected age of an IOS and its measured average skin temperature (hypothesis 5).

Thus out of 6 hypotheses, three hypotheses were confirmed and three hypotheses were rejected.

The main goal of this thesis was to quantitatively prove or at least indicate the existence of IOS. The confirmed hypotheses 1b, 2 and 3 show that it is possible to localize IOS with thermography. It is still the authors' belief that osteopathic manual palpation is the best measuring tool to detect an IOS. The human hand has great palpation qualities which cannot be praised enough.

Hypothesis 1b (see subchapter 5.3.1) might not be positively confirmed. However, according to the clinical observation of some osteopaths, a strong neurophysiological link between the interosseous membranes within a person (Pelletier et al., 2006) may cause both lower legs to react as a unit. This observation might lead to the fact that an IOS process within one leg might also affect the neurophysiological activity of the contralateral leg.

Vitality and age of an IOS was not linked to the measured temperature values of the overlying skin. This might be due to the fact that the age of an IOS was only guessed by the examination subjects and that the nature of vitality might not be expressed through infrared radiation. Further detailed research is needed to assess links between the mentioned parameters. The results indicate that in time, temperature values do not change according to hypothesis 5. This might empower the theory stated in Swiss International College of Osteopathy that a lesion which is "non-physiological without respect of axis"[23] (an IOS) does not recover itself in time.

In order to gain more knowledge of the connection between age and temperature values of an IOS (or any other evaluation method as manual palpation or another measurement device), the experimental setup would have to be completely different, actually very unethical: The examiner would have to *create* intraosseous lesions with a standardized method within subjects (like Louisa Burns DO, as described by Norman Allan DO (1986)) and then test the outcome after a defined length of time. As the author assumes, this experiment setup is very difficult if not impossible to realize within a thesis and unethical if performed on human subjects.

The author suspects that further research with the same setup and a higher sample size could possibly confirm and even complement the outcome of this study. In terms of quantitatively measuring vitality, this study indicates that one might need another measuring device which can quantify a broader spectrum of radiation.

[23] Definition: This is an osteopathic lesion of a structure which is not in its physiological position and does not respect its given physiological axes.

6 CHAPTER SIX: SELF-CRITIQUE

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6.1 POSITIVE ASPECTS

The accomplished goal of measurably indicating the existence of IOS and creating a path for future research on this phenomenon is the most positive aspect of this thesis. Research like this is important to help osteopathy gain increased acceptance in the medical world. By medical standards, IOS are not detectable. But it is important to mention that IOS, as already mentioned by numerous Osteopaths before in this thesis, have a direct negative effect on its surrounding joints and thus affect regional and global mobility and motility.

6.2 NEGATIVE ASPECTS

Below is a list of what did not go as well as expected and/or desired for the author:

- **Sample size**: The sample size of 43 (20 in the case group, 23 in the control group) should be larger to gain more convincing statistical data and thus to gain more credibility.
- **Finding *strong* IOS in the tibia**: Although the author could find 20 subjects with an IOS of the tibia, only a small number had a well-marked intensity of intraosseous expression (like bone rigidity and lack of vitality). The author underestimated the difficulty to find appropriate subjects with no exclusion criteria within the given timeframe. The author suspects that this factor resulted in relatively weak data concerning intraosseous intensity.
- **Blinding during examination**: This research project was conducted by only one examiner, thus optimal blinding was not given. The examiner was able to view both lower legs before and during manual palpation which could have indicated intraosseous locations by visual detection of scar tissue et cetera. The

examiner recruited most subjects. Information about location(s) of possible IOS might have been revealed before manual palpation.

- **Blinding during data processing:** The author itself defined the tibial areas in the thermographic software so the software could calculate all selected temperature points (pixels) and output the maximum, minimum and average temperate values. This increases the chance that the author might have manipulated the data by consciously selecting colder or warmer areas within the thermal picture.
- **Questionnaire**: In hypothesis 5, the age of existing AIO‘s[24] are only estimations given by the subjects. These estimations led to data which connected an IOS with an existing AIO which again led to the age of an IOS. If the subjects gave false information or the question "which AIO do you think led to your present complaints" was answered incorrectly, the data would be false. So there is a chance that hypothesis 5 cannot be accurately accepted or rejected with the given data. Additionally, one possible important pathology which could affect shell temperature was not covered by the questionnaire: Rheumatoid arthritis. This could lead to false temperature readings of the anterior tibial skin surface, especially if the knee would be affected.
- **Measuring instruments**: Two measuring instruments were used: Thermal camera and osteopathic manual palpation. Osteopathic manual palpation was, until this research project, the only possible way to detect and classify an IOS. Manual palpation has questionable inter-reliability according to some research, although Druelle DO (2012) claims that self-performed inter-reliability

[24] AIO = accident/injury/operation

experiments with osteopathic students and certified osteopaths within his colleges created following results: With a predefined scale[25] to classify expression of vitality, osteopaths classified the found vitality with a difference of a maximum of 0,5[24].

The infrared camera used in this research had only been applied once for medical research prior. Although international standards were fulfilled, the device itself was not thoroughly validated by previous research.

- **Thermography in relation to pathology**: As mentioned in Chapter 2, thermography may detect many forms of pathological processes, not only IOS. So in this setup it is not 100% sure that the subjects are free of pathology in the tibial area. So there is a slight possibility that the measured heat pattern is falsified by an unknown pathology.
- **Scope of the research**: In order to give this experimentation more power, post-treatment thermographic assessment would have been optimal in order to show change in thermal patterns. However, it is important to note that under other circumstances and with a greater time frame, the proposed research setup would be the better option. The setup mentioned above would be an interesting follow up thesis for someone else in order to strengthen and broaden the results gained in this thesis.

6.3 Advice on Replication of this Research

If this research would have to be repeated, following aspects should be considered in order to achieve more accurate results:

- Using a larger sample size

[25] scale details: 0 = no vitality / 0,5 / 1 / 1,5 / 2 = normal vitality / 2,5 / 3 = very high vitality

- Finding subjects with strong IOS
- Use of an assistant to ensure blinding
- Use of an infrared camera with a higher resolution, and ideally a device which has been used in numerous previous medical research projects
- Maybe the use of an additional measuring device like a bone densitometer to compare results
- Hypothesis 5: Reject this hypothesis or try to reformulate and use a different approach to estimate the age of an IOS. Data acquisition is too inaccurate (see Subchapter 6.2)

It would be great to find someone who could repeat this research to possibly gain more expressive data. The only downside is that a proper thermal camera is quite costly. One could rent a device but this would again decrease the chance to gain high sample size with representative subjects. The author of this thesis bought the EC 060 device and sold it again after finishing his data collection in order to finance the statistical workout.

6.4 ADVICE ON FUTURE RESEARCH

As already mentioned before, a wider setup of experimentation would be advised to gain stronger results. Ideally, all subjects would have to undergo following steps:

1. First examination with fully blinded manual palpation (ideally by multiple examiners) and collection of infrared data.
2. Consecutive treatments of IOS
3. After a predefined timeframe: Manual reassessment and recollection of infrared data.

This setup could show a) that intraosseous strains can be found with an infrared device and b) that the temperature values actually change by treating IOS.

Furthermore, one could use infrared imaging to compare different treatment approaches. This would lead to information on the efficiency of different techniques.

7 CHAPTER SEVEN: CONCLUSION

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Eighty-six adult tibias (46 in the control group, 40 in the case group) were examined with manual osteopathic palpation and with thermal imaging following international standards. Most importantly, the average temperature values of the anterior skin of the tibia were compared to data given by a questionnaire and to data from the examination protocol. The main goal was to quantitatively indicate the existence and to help understand the nature of IOS.

Statistical analysis has shown a correlation between manual palpation and thermal imaging. Not by exactly showing the location of an IOS on a picture, but by indicating its presence by lowered regional heat radiation of the skin. Data clearly shows that an affected leg with an IOS has lower skin temperature in the directly overlying area, compared to its contralateral unaffected leg. Data also indicates the fact (with low statistical significance) that the more rigid an IOS, the lower the found skin temperature. This could strengthen Browns DO (2011) and Druelles DO (2012) thought that an IOS creates or is expressed by a local change of blood and fluid flow. The following sentence could now be added on:

> An intraosseous strain negatively affects local physiological processes. The more rigid an intraosseous strain, the lower the physiological activity (expressed by temperature) of its overlying skin.

Unfortunately, comparison between vitality and temperature values, and age of an IOS and temperature values, did not give the expected results. Hypotheses 1b, 4 and 5 could not be confirmed. Hypothesis 5 was difficult to confirm due to the fact that the subjects had to estimate the age of their possible IOS. This data acquisition was entirely subjective and contains a high potential for errors. However, these results might strengthen the theory from Swiss International College of Osteopathy that a lesion which is "non-physiological without respect of axis" cannot release itself in time. Data shows that heat patterns are not correlational with the suspected AIO.

The author also suspects that hypothesis 4 was difficult to accomplish with the given data because only a little number of subjects with an IOS had a strong decrease in vitality. Most subjects presented themselves with quite small IOS expressed with little loss of vitality and slightly reduced rigidity. Hypothesis 1a, as discussed in Chapter 5.4, might be difficult to confirm due to a clinically observed phenomenon within the osteopathic world. It claims that all interosseous membranes (between radius-ulna, between tibia-fibula) contain a strong neurophysiological link with each other and thus may affect each other's blood flow because most important blood vessels pierce the interosseous membrane. Of course this is only one of many possible explanations why the numbers show the given results.

Quantitative infrared image detection of IOS could show the medical and osteopathic world that there is a specific stage between “not-fractured” and “fractured” bone (Keaveny & Bouxsein, 2008) - the IOS. Additionally, the author suggests to add a palpation parameter to finding IOS:

- **NEW**: Manual thermal palpation of the overlying skin areas of a bone
- Palpation of rigidity/spring of the bone
- Palpation of expression of vitality of the bone

This "new" palpation parameter might increase speed and effeiciency in locationg IOS in affected patients. The author is aware that many Osteopaths already consciously or unconsciously palpate temperature changes of the body's surface while assessing their patients, but this research adds importance and supports this approach with quantitative data.

The author is also aware that this thesis is only the starting point in trying to understand testing, treating and classifying IOS. Further research on certain treatment protocols would give more precise and quantitative information on the nature of IOS and the effectiveness of osteopathic treatment of IOS.

Although the assessment of IOS is not thoroughly described in literature, the author tried to scientifically underline all methods being used, such as manual palpation of the bone's spring and its expression of vitality. Expression of IOS, its rigidity and its expression of vitality is still a vaguely described and researched area, even within the osteopathic community. Thanks to qualitative research done by Brown DOMP (2008) and Mummery DO (2008) and to research and lecturing performed by Chauffour DO & Prat DO (2002), a certain foundation is given to this research.

The author hopes that this research helps to understand a little more about the true nature of intraosseous strains, whether it might be of mechanical, fluidic or energetic nature - or maybe a mix of all?

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APPENDICES

APPENDIX 1: CHAPTER THREE: METHODOLOGY OF THE THESIS PROTOCOL

3 CHAPTER THREE: METHODOLOGY

3.1 RESEARCH STRATEGY

3.1.1 SAMPLE SIZE

Descriptive statistics (crossed table) will be used in first line, thus comparing two groups of data of a minimum of 10 samples. In order to draw statistically significant data, Huettenmoser Oliva (2011), a statistician, advised to achieve a minimum sample size of 30 subjects (N=30). This means this thesis will present a minimum of 15 subjects in the case group and 15 or more subjects in the control group (with *no* intraosseous strains).

From a methodological standpoint, we can assume that a sample size as large as 30 or more has a normal distribution of sample mean score (Huettenmoser Oliva, 2011). In this study the sample size was of N=86 (20 affected tibias in the case group (leg A), 20 unaffected tibias in the case group (leg B), and 46 tibias in the control group (C&D)).

3.1.2 SAMPLE SEARCH

Various methods are being used to find appropriate subjects for this study, as a publication within the authors' clinic through a leaflet or directly via the author or his assistants, as a search through two friends which are senior football (www.fc-maur.ch) and ice-hockey club members and as a search through the internet (www.muntinga.ch , www.facebook.com (via the public site "therapiepraxis muntinga" on Facebook) and www.sacralmusings.com).

Randomization of the subjects is given because any healthy person without known pathologies of his or her legs, age 22 and above can be part of this experiment. Because this experiment does *not* use a placebo control group for comparing it to another group which receives a therapeutic intervention, randomization is generally not necessary.

3.1.3 INCLUSION AND EXCLUSION CRITERIA

3.1.3.1 INCLUSION CRITERIA

- Inclusion criteria for the case group:
  - Age: 22 years and above (end of tibial growth phase is approximately with the age of 21)
  - Ideally: History of known lower leg trauma and repeated mechanical stress
  - Confirmed intraosseous strain with osteopathic manual palpation by the examiner
- Inclusion criteria for the control group:
  - Age: 22 years and above

3.1.3.2 EXCLUSION CRITERIA

- Exclusion criteria for the case group:
  - Existence of bilateral intraosseous strains
  - Known fractures of the lower leg (tibia and/or fibula)
  - Recent superficial or deep injuries (three weeks or earlier) at the site of both tibias due to inability to compare temperatures reliably (active inflammation phase)
  - Any arterial, venous or lymphatic pathology
  - Any (sub-)acute skin condition (allergies, eczema, rash, et cetera)
- Exclusion criteria for the control group:
  - Existence of an intraosseous strain within any lower leg bone (tibia and/or fibula)
  - Any known superficial or deep injuries (including fractures) of the tibial area younger than 16 weeks

- Any arterial, venous or lymphatic pathology
- Any (sub-)acute skin condition (allergies, eczema, rash, et cetera)

3.1.4 VARIABLES

- Independent variables:
  - Age of subject
  - Gender of subject
  - Inglehart Index value
  - Weekly frequency of sport activities
  - Number of known mechanical traumata
  - Suspected age of mechanical traumata
  - Palpatory results: Location, Rigidity and Vitality
- Dependent variables:
  - Skin temperature measured by thermography in degree Celsius

3.2 MEASURING INSTRUMENTS

3.2.1 THERMOGRAPHY

In this thesis, the author uses a thermographic device produced and sold by *Trotec*[26], details shown below:

Figure 2. Trotec EC 060 Infrared Camera (Trotec, 2011)

[26] Trotec, see online www.trotec24.com

The technical description of this device is as following:

> ”EC 060 Infrared Camera - First-Class Thermography
>
> The EC 060 is yet another infrared camera in the hugely-successful infrared camera series from Trotec. The EC 060 is equipped with a variety of valuable features including a maintenance-free, uncooled image sensor with a detector resolution of 160 x 120 measuring spots and a thermal sensitivity of 0.1 °C. And because the EC 060 is also a fully-radiometric infrared camera which enables you to take thermal images in a temperature range from -20 °C to +250 °C it has already set new standards with regard to price and performance.
>
> - An overview of the EC060’s many favorable features:
> - Measuring range from -20 °C to +250 °C
> - Fully radiometric infrared camera in a compact design
> - High image repetition frequency of 50/60 Hz
> - Maintenance-free operation due to microbolometer technology
> - Ergonomic form and extremely light
> - High thermal sensitivity of 0.1 °C
> - Automatic cold spot / hot spot detection
> - One movable measuring spot
> - Minimum focal distance of only 10 cm
>
> The camera’s high image repetition frequency ensures permanent real-time image representation of thermal images and the mini SD card included in the scope of delivery can easily save thousands of thermal images.” (Trotec, 2011)

In order to qualitatively and quantitatively process the thermal images taken, the Trotec EC 060 comes with a computer software called *IC-Report Standard*. Within this software, the author can do the following:

- Open and view thermal images taken by Trotec EC 060
- Show temperatures (exact, maximum, minimum and average in degree celcius):
  - At any location
  - Within in a defined area
  - Along a defined line

The Trotec EC 060 has been used in medical research before (Wolter & Kieselbach, 2011) and was found to be accurate for measuring living tissue temperature. This study measured skin temperature of the fingers before and after spinal cord stimulation with an electrode in subjects with Raynaud‘s Syndrome. Raynaud‘s Syndrome is known to be a vasospastic condition affecting primarily the distal resistance vessels of extremities (Wolter & Kieselbach, 2011). Next to thermal data, clinical effects as pain in both hands were observed. Results were that the therapeutic intervention of spinal cord stimulation effectively increased peripheral blood flow (vasodilation) and decreased subjective pain in both hands. Important to note is that the thermal readings significantly correlated negatively with pain levels. Thus increased peripheral blood flow (vasodilation induced by spinal cord stimulation) led to increased heat readings of the skin surface of the fingers. The article (Wolter & Kieselbach, 2011) did not mention if they used international standards of thermal imaging and did not describe exact examination procedures and parameters such as room temperature, air humidity, examination room design. This fact might imply that absolute temperature readings might not be very exact, but the temperature difference (before and after intervention) should have been exact enough to provide valid statistical numbers.

The International Academy of Clinical Thermology (Thermology, 2002) doesn’t recommend specific infrared camera equipment, it gives a list of minimum specifications the used infrared device should have:

- Detector response with the spectral bandwidth encompassing 8-10 micron region
- Repeatability and precision of 0.1 °C detection of temperature difference
- Accuracy of +/- 2% or less
- Significantly variable contrast (level) settings
- A maximum scanning time of 4 seconds or less with real-time capture
- High-resolution image display for interpretation
- Ability to archive captured images
- Image processing and data capturing software

All above mentioned requirements are given with the Trotec EC 060. Last but not least, the Trotec EC 060 is calibrated to ensure maximum accuracy.

3.2.2 MANUAL PALPATION AS AN IDENTIFICATION AND CLASSIFICATION TOOL FOR INTRAOSSEOUS STRAINS

Little written information is found on a methodology for testing intraosseous strains. The Swiss International College of Osteopathy teaches the existence of intraosseous lesions and defines what they feel like on a palpatory level, but little information is given for exact testing and locating. Instead, Chauffour DO & Prat DO (2002) and Heller DC (2005) talk about testing the spring or stiffness of the bone in all spatial dimensions and give precise instructions how to locate and define the intraosseous strain in all three dimensions. The author will use a simplified testing protocol (see Appendix 3) using local/regional spring tests with local listening of tissue vitality (as a consequence of the qualitative thesis from Brown DOMP (2008) and lectures from Druelle DO (2011b)).

3.3 EXPERIMENTATION METHOD AND DATA COLLECTION METHOD

3.3.1 FILLING OUT THE QUESTIONNAIRE AND SIGNING THE FORM OF CONSENT

Each subject has to sign a form of consent (see Appendix 6) and fill out a short questionnaire before examination. This examination form will be given in an envelope (blinded) and will not be shown to the examiner until after manual osteopathic examination.

DETECTION OF INTRAOSSEOUS STRAINS IN THE ADULT TIBIAL BONE:
OSTEOPATHIC PALPATION AND THERMOGRAPHY

ID No.

Fragebogen

Vorname, Nachnahme: ____________________________
Geschlecht: ( ) M ( ) W
Geburtsdatum: ___ . ____ . ___________ (tt.mm.jjjj)

Bitte Passendes ankreuzen und gegebenenfalls Ort (Seite links/rechts) ankreuzen:

Beschwerden im Knie-, Fuss- oder Unterschenkelbereich?
☐ NEIN
☐ JA, Ort: ( ) links ( ) rechts

Knochenbrüche der Unterschenkelknochen?
☐ NEIN
☐ JA, **0 - 16 Wochen** alt sind, Ort: ( ) links ( ) rechts
☐ JA, **älter als 16 Wochen** sind, Ort: ( ) links ( ) rechts

Unfälle/Verletzungen/Operationen mit den Knien/Unterschenkeln/Füssen? (mehrere ankreuzen ist erlaubt)
☐ NEIN
☐ JA, **0 - 3 Wochen** alt, Ort: ( ) links ( ) rechts (A)
☐ JA, **1-4 Monate** alt, Ort: ( ) links ( ) rechts (B)
☐ JA, **5-12 Monate**, Ort: ( ) links ( ) rechts (C)
☐ JA, **1-2 Jahre**, Ort: ( ) links ( ) rechts (D)
☐ JA, **3-5 Jahre**, Ort: ( ) links ( ) rechts (E)
☐ JA, **6-10 Jahre**, Ort: ( ) links ( ) rechts (F)
☐ JA, **11+ Jahre**, Ort: ( ) links ( ) rechts (G)

Welches der oben gennannten Unfälle/Verletzungen/Operationen ist Ihrer Meinung nach **verantwortlich für Ihre aktuellen Beschwerden?** (bitte A-G ankreuzen)

A / B / C / D / E / F G

Arterien/Venen-Problematiken oder andere Krankheiten in den Beinen?
☐ NEIN
☐ JA, Ort: ( ) links ( ) rechts

Hautkrankheiten an den Unterschenkeln (Psoriasis, etc.)?
☐ NEIN
☐ JA, Ort: ( ) links ( ) rechts

Wie oft pro Woche machen Sie normalerweise **Sport** (mehr als 15 min.)?
☐ 0
☐ 1
☐ 2
☐ 3
☐ 4
☐ 5
☐ mehr: ______

Autor: Edward Muntinga, CO, 2011

Figure: 3. Questionnaire page 1. To be filled out by each test subject of both sample groups

DETECTION OF INTRAOSSEOUS STRAINS IN THE ADULT TIBIAL BONE:
OSTEOPATHIC PALPATION AND THERMOGRAPHY

ID No.

Welche beiden der folgenden Ziele halten Sie persönlich für besonders wichtig? (bitte unten in die Kästchen eingeben)

A: Aufrechterhaltung der nationalen Ordnung.
B: Verstärktes Mitspracherecht der Menschen in wichtigen Regierungsentscheidungen.
C: Kampf gegen steigende Preise.
D: Schutz der freien Meinungsäusserung.

☐ Welches dieser Ziele sehen Sie als **wichtigste** an? Bitte tragen Sie den Buchstaben A, B, C oder D ein

☐ Welches dieser Ziele sehen Sie als das **zweit-wichtigste** an? Bitte tragen Sie den Buchstaben A, B, C oder D ein

Figure: 4. Questionnaire page 2. To be filled out by each test subject of both sample groups

In the following paragraph, you find an English translation:

Questionnaire:

- Name, Gender, Birth Date
- Please tick appropriate and eventually the location (left/right):
  - Complaint(s) in knee, foot or lower leg? NO, YES (left/right)
  - Fracture(s) of the lower leg(s)? NO, YES 0-16 weeks old (left/right), YES 16+ weeks old (left/right)
  - Accident(s) / Injury in knee, foot or lower leg? NO, YES 0-3 weeks old (left/right) A, YES 1-4 months old (left/right) B, YES 5-12 months old (left/right) C, YES 1-2 years old (left/right) D, YES 3-5 years old (left/right) E, YES 6-10 years old (left/right) F, YES 11+ years old (left/right) G
  - Which of the above injury might be (in your point of view) the cause for the today's complaints? A/B/C/D/E/F/G
  - Any arterial/venous pathology in the leg(s)? NO, YES (left/right)
  - Any skin disorders in the lower leg(s)? NO, YES (left/right)
  - How many times per week do you perform sport activities (more than 15 min): 0/1/2/3/4/5/more
  - Inglehart Index questions (see chapter 3.4.4)

3.3.2 CAPTURING THERMAL IMAGES

First, there is a thermal image taken of the anterior side of both tibias with the Trotec EC 060 camera. It is mounted on a commercially available camera tripod (EF digital star 700, sold by hama). The construct camera-tripod looks like the following:

Figure: 5. Infrared camera and its tripod

Average temperature of the whole anterior side of both tibias will be collected in each subject. The examiner does not see the heat pattern of the infrared image, because the Trotec EC 060 has a dual-image mode where one only sees a normal picture and at the same time the camera records a infrared image without showing it. Images being taken by an independent assistant and this "double-image" mode ensures that the examiner is single-blinded (author doesn‘t know how the temperature readings look) before the osteopathic palpation examination.

International standards defined by Diadikes & Bronzino (2008) and Ring et al. (2004) will be used to ensure proper infrared imaging:

- **Examination room type:**
  - Minimum size of 2x4 meters. Actual examination room size is 16 square meters.
- **Room climate:**
  - Relative humidity: It is recommended to have a dry environment to avoid sweating of the skin, thus approximately 35-55% - ideally 45%.

- Room temperature: To avoid vasoconstriction of the skin due to cold temperature and to also avoid sweating of the skin due to hot temperature, a 20-25 ˚C ambient room temperature will be used. This is no problem in this research project, because the planned examination room has floor heating with a precise thermostat.
- Air conditioning: No air conditioning equipment is recommended and overall low air speed within the examination room. The actual examination room has no air conditioner and its door and windows are airtight.

- **Test person information before examination:** Before the infrared picture(s) will be taken, the subject has to sign a form of consent (see Appendix 6) at least 24 hours before examination. This form also states requests by the author to ensure that the measured temperature during examination will be as precise as possible:
  - No usage of cosmetics (skin lotions, ointments et cetera) on the day of examination.
  - No alcohol intake on the day of examination.
  - No smoking approximately 1 hour before examination.
  - No large meals and excessive tea/coffee intake on the day of the examination.
  - Avoid tight fitted clothing on the day of examination.
  - Avoid physical exertion on the day of the examination.
  - Avoid any manual/physical therapy on the day of the examination.
  - Drugs affecting the cardiovascular system (blood pressure medication et cetera) should be reported to the examiner.

- **Pre-imaging equilibration:** On arrival at the examination, the subject will be informed of the examination procedure, instructed to remove appropriate clothing (in this study: pants, both socks or any stocking which could cover the foot and the tibia), and asked to sit or rest in the examination room for a fixed time of 15 minutes.
- **Position for imaging:** A standard view of the tibias will be used, see Figure below. The complete anterior view of the tibias will be pictured, including feet and knees. Distance between toes of the subject and mid-foot of the tripod is 240 cm and the height of the midpoint of the camera lens from the ground will be 51 centimeters.

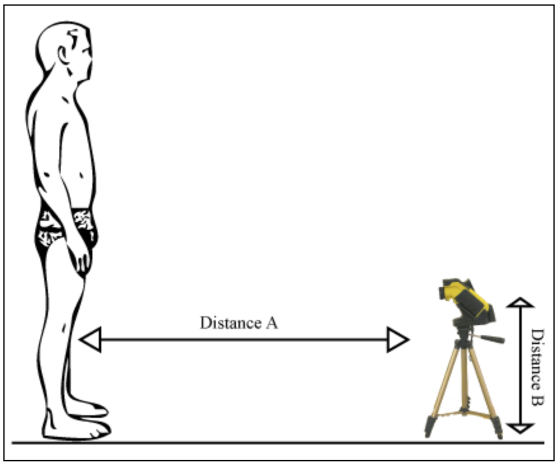


Figure: 6. Distance A between tibia and IR Camera: 240 centimeters. Distance B between ground and midpoint of camera lens: 51 centimeters.

The reason why the whole anterior side (superior border: inferior margin of the patella, inferior border: horizontal mid-line between lateral and medial malleolus) of the tibia will be taken for calculating the average temperature and not only the exact location of the intraosseous lesion is that thermal imaging quantitatively shows current state of skin blood flow (Diadikes & Bronzino, 2008; Plaugher, 1992; Ring, unknown; Ring & Ammer, 2000; Ring et al., 2004) and the tibia is mainly nourished by the anterior tibial artery (see chapter

2.2.2.1 for details) which also vascularizes the anterior skin surface of the lower leg (Schünke et al., 2005).

The logical assumption to this anatomical fact is that an intraosseous strain might alter skin temperature globally at the anterior surface of the lower leg and not only its local spot. Standing position of the subject is chosen to ensure exact distance between the camera and the subject. According to Roy, Boucher & Comtois (2010) there are no differences between prone and standing temperature measurements if symptom-free subjects are given 8 minutes to acclimate (in this study, 15 minutes are being used) before performing thermal imaging.

3.3.3 PERFORMING THE OSTEOPATHIC MANUAL EXAMINATION

After having the thermal image taken of both tibias in one image and annotation of the infrared image number on the examination form by the assistant, palpation tests are performed by the examiner and their result will be noted in an examination form. Detailed description of the used palpation tests are found in the appendices.

DETECTION OF INTRAOSSEOUS STRAINS IN THE ADULT TIBIAL BONE:
OSTEOPATHIC PALPATION VERSUS THERMOGRAPHY

EXAMINATION FORM

ID No.

Date of examination: (dd.mm.yyyy) ____________________
Room temperature: ________ degrees celcius
Room air humidity: ________ %

Location(s) of intraosseous strain(s): Mark with a circle and number with "area 1/2/3"

Side + ☐ RIGHT ☐ LEFT ☐ **NONE**

IR Image number(s):

____

____

Notes:

Spring tests:

Area 1	Area 2	Area 3
anterior-posterior spring: 0 / 1 / 2 / 3 torsion test: 0 / 1 / 2 / 3	anterior-posterior spring: 0 / 1 / 2 / 3 torsion test: 0 / 1 / 2 / 3	anterior-posterior spring: 0 / 1 / 2 / 3 torsion test: 0 / 1 / 2 / 3

Vitality tests:

Area 1	Area 2	Area 3
0 / 1 / 2 / 3	0 / 1 / 2 / 3	0 / 1 / 2 / 3

Definitions:
spring: 0, 1, 2, 3 (0= normal, 1 slightly hard, 2 hard, 3 very hard)
vitality: 0, 1, 2, 3 (0= normal, 1 slightly low, 2 low, 3 none)

Autor: Edward Muntinga, CO, 2011

Figure: 7. Examination form

Table: 4. FINDINGS NOTED WITHIN MANUAL EXAMINATION

Spring tests:	Vitality listening:
0 (normal)	0 (normal)
1 (slightly hard)	1 (slightly low)
2 (hard)	2 (low)
3 (very hard)	3 (none)

78% of the Osteopaths from all over the world interviewed by Mummery (2008) use descriptive palpation, 40% used visual observation of vitality, 34% use palpation results vitality or no vitality, 34% use patient's verbal description of their own vitality and 19% use a number scale from 1 to 10. The author chose the scale 0/1/2/3 to be able to convert the received palpatory sensations form the examination into statistically useful values.

3.4 BIAS

3.4.1 SAMPLE BIAS

- All subjects have to avoid a list of activities and things on the day of the examination (see chapter 3.3.1). The examiner cannot control if all recommendations have been followed by the subjects or not and has to trust that they tell the truth.

3.4.2 METHODOLOGY BIAS

- The examiner doesn't know the result of the questionnaire and the infrared image taken (questionnaire and thermal images are performed by an independent assistant) before manual examination. These are the procedures which ensure partial single-blinding.
- Dividing all subjects into both groups solely depends on the palpation capabilities of the examiner. So if the examiner doesn't palpate well, subjects might get categorized into the wrong group.
- The used camera type (Trotec EC 060) has only been used within one medical study before (Wolter & Kieselbach, 2011), thus its validity is not 100% ensured, although all standard requirements are given (see Chapter 3.2.1) and strict image taking standardization is being used to ensure similar infrared images.

- Definition of the exact area of the anterior skin surface of the lower leg within the software used to read out temperature values. This area is being drawn manually on the computer-screen with computer-mouse movements, thus 100 percent exact definition of all lines which form this area is not possible.
- Scars of the skin along the anterior side of the lower leg are not being taken into consideration. The examiner is not perfectly single-blinded because he could conclude any previous trauma by detecting mechanical trauma. The author considered the possibility to exclude every subject with any scars along the lower leg(s) but decided to *not* do this. Scars can be an indication of any trauma, even "just" a small cut years ago. This exclusion criteria would decrease massively the possibility to find enough suitable subjects for the case group.

3.4.3 Bias Control Methods

To control the to be avoided activities of the subjects before examination is not possible. The examiner has to trust the information given by each subject. The examiner will be single-blinded before manual osteopathic palpation procedure. The subjects will be told to tell no information about their symptoms and problematics (if there are any) until after the manual osteopathic palpation procedure.

3.4.4 Third Variables Control method: Inglehart Index

As advised by Hüttenmoser Oliva (2011), a third variable control method should be used to exclude spurious correlation results.

> "A confounding variable, also known as a third variable or a mediator variable, can adversely affect the relation between the independent variable and dependent variable. This may cause the researcher to analyze the results incorrectly. The results may show a false correlation between the dependent

> and independent variables, leading to an incorrect rejection of the null hypothesis." (Bauer, 2009; Shuttleworth, 2008)

In order to control spurious correlations, each subject will be asked to answer two additional questions which will collect data for a third variable, the Inglehart Index:

> *"The Inglehart index of post-materialism is measured by people's priority for low inflation and order. We use regression analysis to correct national averages of the Inglehart index for the effects of observed inflation and (violent) crime rates for selected European, Asian and South American countries. Low inflation and low crime rates significantly increase the Inglehart index, but we also observe a trend towards post-materialistic values. This trend cannot be explained by economic growth alone."* (Oliver & Richard, 2003)

The text used for creating the form to determine the Inglehart-Index of each subject is being taken from Bortz & Döring (2006).

Table: 5. QUESTIONS TO DETERMINE INGLEHART INDEX

If you had to choose among the following things, which are the **two** that seem the most desirable to you? A: Maintaining order in the nation. B: Giving people more say in important political decisions. C: Fighting rising prices. D: Protecting freedom of speech Which one of the mentioned things above do you classify as MOST IMPORTANT: Please mark letter A, B, C or D. Which one of the mentioned things above do you classify as SECOND IMPORTANT: Please mark letter A, B, C or D.

3.5 ETHICAL CONSIDERATIONS

This research will performed in such a way that anonymity of each subject is given at all times. After data collection, examination protocols will be anonymized by not showing the subjects name.

Each infrared image will be numbered with the number of the corresponding subject. Image anonymization is not necessary because thermal images have a low resolution in thermal coloring (“rainbow coloring”) and can not be matched to a person.

All research data and thermal images will be stored securely by the author and a copy will be offered to each subject if requested.

APPENDIX 2: DOCUMENTATION OF APPROVAL OF CHANGES TO THESIS PROTOCOL

1. THESIS PROTOCOL CRITIQUE DOCUMENT NR.1

Thesis Protocol for Edward Muntinga Recommendations and Comments October 23, 2011 by Marie Colford D.O. and Paul Wagner D.O.

A. Osteopathic and scientific contribution

1. Hypothesis: Not accepted due to unclear proposal of the goal of the research and poor research model. Model lacks pertinent osteopathic contribution.
    1. Hypothesis should be reworded to include correlations between the palpation and treatment of intraosseous lesions pre and post treatment as measured by thermography. This is required to demonstrate a change that is quantifiable pre and post treatment by thermography thus giving credence to the existence of intraosseous lesions and their palpation and treatment as no other proof is being offered.
    2. There must be an understanding that thermography does NOT measure blood flow so conclusions cannot be drawn as to the relation of blood flow to temperature as this is not being measured. It can, however, be proposed in the discussion. It must be acknowledged that changes in temperature can be the result of many different factors.
2. In Literature Review: Must include discussion of current knowledge of intraosseous lesions. How are they evaluated and treated and the current measurement tools that are used.

i. Must discuss articles in more depth, and within a more critical framework. c. Theoretical Model : Model as proposed reveals little osteopathic content nor furthers

understanding of the existence of the intraosseous lesion or how detection and treatment would occur – rather it makes a weak correlation between an instrument and findings and does not lead to greater understanding as to osteopathic intervention nor result of treatment.

B. Methodology

1. Research Design: Choice of research of design is not accepted. It was recommended that a pre - test, treatment and post - treatment measurement is taken with thermography. Therefore an experimentation becomes part of the new model. It is recommended that more than one post - treatment measurement be taken in order to increase the power of the study and osteopathic understanding of the proposed correlation.
2. Measuring Tools: An increase in the description of the measurement tool in terms of the specifications and independent validation by a third party.

c. Number of subjects is to be determined by a statistician based on the research model used.

4. Evaluation of research and experimental procedures (osteopathic discovery of intraosseous lesions and experimentation procedures) must be described in the methodology.
5. Must increase description of the methodology and include how multiple factors will be controlled.
6. Inclusion and Exclusion criteria must be separated in the protocol and elaborated.
7. Must submit forms for data collection and analysis in the protocol.
8. Must remove statement from the conclusion that "only this explanation model can also explain why the..."
9. Should avoid generalisations and pre - conclusions within scientific writing.
10. Must decide whether it is a single or double - blind study.
11. What is selection process for subjects and determination of the presence of an intraosseous lesion and subsequent randomization of subjects?

C. Format

1. Document was lacking in content and elaboration of process.
2. Ensure proofreading of document for control of language errors.

Conclusion: Protocol was NOT accepted. Must submit a new protocol for January 1, 2012

2. THESIS PROTOCOL CRITIQUE DOCUMENT NR.2

Revised Thesis Protocol for Edward Muntinga
Recommendations and Comments, Jan. 13, 2011

by Marie Colford D.O. and Paul Wagner D.O.

The revised Thesis Protocol has been reviewed by the members of the protocol committee.
Overall there has been an improvement in the writing of the protocol; however recommendations made by the jury were not followed. A revised protocol has been proposed and accepted conditional that corrections are made. These corrections may be reviewed by the Thesis Director, Julie Brown, DO. The present hypothesis is accepted.

1. **Abstract**: the purpose of this study- must add intraosseous strains of the tibia as no other area is being evaluated. Therefore discussions and conclusions will be limited to the tibia.

2. **Citations**:
   a) The thesis/ protocol cannot use the results of the Pilot Study by Edward Muntinga. The study was neither published nor peer reviewed. It may be referred to as an observation or anecdotal information.
   b) There is neither a description nor critique of the article by Wotler and Kieselbach, 2011 which validates the measuring tool.

3. **Methodology**:
   a) Number of subjects is to be determined by a statistician based on the research model used (proposed corrections to protocol, Oct.23, 2011). This recommendation to the student was not followed and has to be corrected.

   b) Research model: it appears that there are an inadequate number of subjects to validate a tool. There are no repeat trials. The present model refers to only the tibia. The model has to be corrected to represent an observation and not a validation.

   c) Testing methodology: remove testing methodology by Chauffour and Pratt. According to the student, he has not taken any courses from these authors and cannot presume to use evaluations tools for which his palpation has not been validated by these authors. The protocol for evaluation that he cited is both inaccurate and incomplete. He may use tools taught in the college and through his own personal experience. His palpation must be validated by a teacher of the college prior to commencement of the experiment.

   d) Single blind- clarify that the single blind refers only to thermography results during the study. Based on the inclusion/exclusion criteria, the research student will know exactly who the subjects in both groups are. There should be an independent evaluator taking the thermography results to ensure the single blind.
4. **Ethics**: remove the words" property of" and replace with "are in the possession of Edward Muntinga for the limited use of research only." Correct pg 39 in the revised protocol- there is no appendix, chapter 9.3.

5. According to the proposed corrections to the protocol, Oct.23, 2011:
   There must be an understanding that **thermography does NOT measure blood flow** so conclusions cannot be drawn as to the relation of blood flow to temperature as this is not being measured. It can, however, be proposed in the discussion. It must be acknowledged that changes in temperature can be the result of many different factors.
   This has not been addressed in the revised protocol. Student persists in making these correlations although does do not discuss nor critique article by Chudaek, 1977.

3. THESIS PROTOCOL APPROVAL DOCUMENT

Gmail - Thesis protocol https://mail.google.com/mail/u/0/?ui=2&ik=1781a74f50&vi...

Edward Mun[redacted]

Thesis protocol

1 Nachricht

Isabel Obrist [redacted] 31. Juli 2012 19:55

An: Edward Mu[redacted]

Lieber Edward

Wollte dir mitteilen, dass die Jury dein Thesis Protocol akzeptiert
haben, kannst jetzt mit der These weitermachen.

Liebe Gruesse
Isabel

--
SICO Swiss International College of Osteopathy
Zinnenstrasse 7, CH-6353 Hertenstein, Tel. +41 (0)41 390 11 82
http://twitter.com/#!/sico_osteopathy
http://www.osteopathy-switzerland.ch

1 of 1 24.10.2012 1:41 PM

Translation: "Dear Edward, wanted to let you know that the jury approved your thesis protocol, you may continue now with your thesis. Best regards, Isabel"

APPENDIX 3: MANUAL PALPATION PROTOCOL

The manual palpation protocol is a mixture of tools taught in Swiss International College of Osteopathy and of techniques developed by personal clinical experience. The palpation protocol was validated by Tara Drew DO, a teacher of Canadian College of Osteopathy and Swiss International College of Osteopathy.

Precise methodology of the manual palpation tests are as following:

1. SPRING OF THE TIBIAL BONE LOCALIZATION AND CLASSIFICATION TESTING METHOD:

a) **Position testing subject**: Lying supine on the treatment table, legs extended. A hard pillow under the knee of the side being tested.

b) **Position Osteopath**: Standing at the foot end of the table.

c) **Action 1**: The Osteopath glides the palm of his hands slowly over the anterior surface from distal to proximal and performs multiple anterior-posterior spring tests at the level of the bone bilaterally and registers normal or abnormal "give" and "spring" of the bone. This action tests the tibia's ability to bend within the anterior to posterior direction:

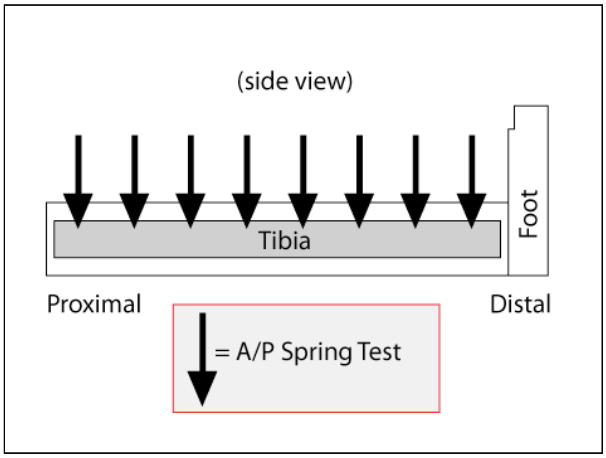


Figure: 11. A/P Spring Test of the tibial bone

d) **Action 2**: To supplement the A/P Spring Test, the Osteopath takes the proximal and distal end of the tibia into his hands and performs a Torsion of the tibia globally by rotating the distal end into one direction and the proximal end into the opposite direction. This test gives additional information of the global longitudinal Torsion capacity of the tibia and additionally confirms the finding of an intraosseous strain.

Furthermore, if the tests above are positive at a specific location, the Osteopath continues with the tests below to additionally confirm an IOS:

2. VITALITY LISTENING OF THE TIBIA:

a) **Position testing subject and Osteopath**: Subject is lying supine, a pillow under the knee of the side being tested. The Osteopath encompasses the area with an IOS proximally and distally with each hand.

b) **Action**: Both hands of the Osteopath encompass the area of the found intraosseous lesion and perform a listening for expansion and retraction. Normal palpation should have a good amplitude and force[27] with an approximate rate of 5-7 per minute (Druelle, 2011a).

[27] same as footnote 11: these parameters are palpated very subjectively and are a consensus of the author professional experience and with the comparison to the contralateral side in each subject being tested.

APPENDIX 4: RECRUITING SUBJECTS FOR THIS RESEARCH PROJECT

End 2011, the author started a recruitment campaign on www.facebook.com, a social communication platform. Please see below the german online version:

Please see next page for a leaflet published in the authors' therapy clinic www.muntinga.ch, text translated into English:

Subjects wanted

FOR OSTEOPATHIC STUDY

Edward Muntinga (Osteopath SICO, CST, PT) performs a study which assesses a new testing method (infrared camera) for bone issues of the lower leg.

You may contact us, if you correspond to the following criteria:

TESTGRUPPE:
• Age: **min. 22** years
• Ideally (ex-)sporters with accident history of the lower legs (blow, fall, etc.)
• **NO bone fractures and/or operations** of the lower legs (ideally confirmed by X-Ray)
• **NO accidents/injuries/operations** of the lower legs more recent than 3 weeks
• **NO problems with arteries/venes** of the legs or any other medical problems
• **NO diseases of the skin** of the lower legs (psoriasis etc.)

Time effort for you would be:

- Before appointment: Fill out a short questionnnaire (2 pages) and sign a form of consent
- The procedure only takes up to 45 minutes

What happens during the assessment:

- You will have to take off your socks and pants, so the author can take a photo of your lower legs with a infrared camera (NO radiation or any side effects)
- Then you will lie on the treatment table (on your back) and E.Muntinga will perorm a gentle and pain free manual testing procedure on your lower legs, approx. 5 minutes.
- If necessary and wanted by the subject, E.Muntinga will treat any found problem on the lower leg immediately
- **ALL information will be kept STRICTLY anonymous!** (picture, name, questionnaire data)

Your benefits:

- If any problem found on the lower leg, E.Muntinga will treat it immediately
- If no local problem found on the lower legs, E.Muntinga will perform a regional/global assessment and will give an estimate what might be the cause of your problem. for free.

If you‘re interested or you have any questions, please contact Edward Muntinga via:

[redacted]

APPENDIX 5: "THINGS TO AVOID ON EXAMINATION DAY" LEAFLET

DETECTION OF INTRAOSSEOUS STRAINS IN THE ADULT TIBIAL BONE:
OSTEOPATHIC PALPATION AND THERMOGRAPHY

ID No.

Measures taken on the day of assessment:

PLEASE READ!

I ask you, on the day of the investigation:

• not to eat large meals
• not to excessively consume coffee / tea
• not to consume any alcohol
• possibly not to wear cosmetics or ointments to the skin of your lower legs
• not to wear tight clothes (v.a. pants)
• not to practice sports immediately before examination

Immediately prior study (approximately 1 hour):

• NO smoking!!!!

THANK YOU!

Autohr: Edward Muntinga, CO SICO, 2011

APPENDIX 6: FORM OF CONSENT

DETECTION OF INTRAOSSEOUS STRAINS IN THE ADULT TIBIAL BONE:
OSTEOPATHIC PALPATION AND THERMOGRAPHY

ID No.

LETTER OF CONSENT

Dear test subject,

Thank you for your willingness to participate in this study. Your participation is greatly appreciated and this study could not take place without you!

- All your personal information will be kept strictly confidential and can only be accessed by Edward Muntinga.
- Your identity can not be recognized by the infrared images; your anonymity is **always** guaranteed.
- The images will be used for research purposes only and are property of Edward Muntinga.

If you have any doubts or questions, please contact: Edward Muntinga, Phone 043 810 81 80, Email: [redacted]

Please confirm:

I am asked on the day of the investigation to enter the treatment room of Edward Muntinga (in therapy practice Muntinga, CH-8122 Binz). I will have to take of my socks and pants. I will allow him to take an infrared image of my lower legs and then to perform a short manual testing procedure.
- If desired, I can have a person of trust accompany me for this assessment.
- I can always pull back from this study without any consequences. My data will deleted if desired.
- I have read this form and give my consent to take part in this study.

Date, place and signature of the subject:

____

Author: Edward Muntinga, CO SICO, 2011

APPENDIX 7: EXAMINATION FORM

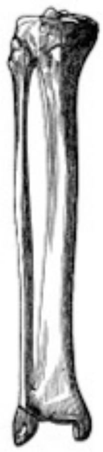
DETECTION OF INTRAOSSEOUS STRAINS IN THE ADULT TIBIAL BONE:
OSTEOPATHIC PALPATION VERSUS THERMOGRAPHY

EXAMINATION FORM

ID No.

Date of examination: (dd.mm.yyyy) ____________________
Room temperature: ________ degrees celcius
Room air humidity: ________ %

Location(s) of intraosseous strain(s): Mark with a circle and number with "area 1/2/3"



Side + ☐ RIGHT ☐ LEFT ☐ **NONE**

IR Image number(s):

____

____

Notes:

Spring tests:

Area 1	Area 2	Area 3
anterior-posterior spring: 0 / 1 / 2 / 3 torsion test: 0 / 1 / 2 / 3	anterior-posterior spring: 0 / 1 / 2 / 3 torsion test: 0 / 1 / 2 / 3	anterior-posterior spring: 0 / 1 / 2 / 3 torsion test: 0 / 1 / 2 / 3

Vitality tests:

Area 1	Area 2	Area 3
0 / 1 / 2 / 3	0 / 1 / 2 / 3	0 / 1 / 2 / 3

Definitions:
spring: 0, 1, 2, 3 (0= normal, 1 slightly hard, 2 hard, 3 very hard)
vitality: 0, 1, 2, 3 (0= normal, 1 slightly low, 2 low, 3 none)

Autor: Edward Muntinga, CO, 2011

APPENDIX 8: QUESTIONNAIRE

FIRST PAGE:

DETECTION OF INTRAOSSEOUS STRAINS IN THE ADULT TIBIAL BONE:
OSTEOPATHIC PALPATION AND THERMOGRAPHY

Questionnaire

ID No.

First Name, Name: ___________________________
Sex: ( ) male ( ) female
Date of Birth: ___ . ____ . ___________ (dd.mm.yyyy)

Please mark accordingly and (if yes), left/right side:

Complaints in foot/lower leg/knee area?
☐ NO
☐ YES, side: ( ) left ( ) right

Bone Fractures of the lower leg?
☐ NO
☐ YES, **0 - 16 weeks** old, side: ( ) left ( ) right
☐ YES, **older than 16 weeks**, side: ( ) left ( ) right

Accidents/injuries/operations of your foot/lower leg/knee? (multiple marks possible)
☐ NO
☐ YES, **0 - 3 weeks** old, side: ( ) left ( ) right (A)
☐ YES, **1-4 months** old, side: ( ) left ( ) right (B)
☐ YES, **5-12 months** old, side: ( ) left ( ) right (C)
☐ YES, **1-2 years** old, side: ( ) left ( ) right (D)
☐ YES, **3-5 years** old, side: ( ) left ( ) right (E)
☐ YES, **6-10 years** old, side: ( ) left ( ) right (F)
☐ YES, **11+ years** old, side: ( ) left ( ) right (G)

Which one of the above accidents/injuries/operations of you foot/lower leg/knee is according to your opinion **responsible for you current complaints**? (please mark A-G)

A / B / C / D / E / F G

Problems with arteries/venes or any other medical problems in your legs?
☐ NO
☐ YES, side: ( ) left ( ) right

Skin diseases on your lower legs (psoriasis, etc.)?
☐ NO
☐ YES, side: ( ) left ( ) right

How many times per week do you normally perform **sport activities** (more than 15 minutes)?
☐ 0
☐ 1
☐ 2
☐ 3
☐ 4
☐ 5
☐ more: ______

Author: Edward Muntinga, CO SICO, 2011

SECOND PAGE:

DETECTION OF INTRAOSSEOUS STRAINS IN THE ADULT TIBIAL BONE:
OSTEOPATHIC PALPATION AND THERMOGRAPHY

ID No.

If you had to choose among the following things, which are the two that seem the most desirable to you?

A: Maintaining order in the nation.

B: Giving people more say in important political decisions.

C: Fighting rising prices.

D: Protecting freedom of speech

Which one of the mentioned things above do you classify as **MOST IMPORTANT:**
Please mark letter A, B, C or D:

☐

Which one of the mentioned things above do you classify as **SECOND IMPORTANT:**
Please mark letter A, B, C or D:

☐

Author: Edward Muntinga, CO SICO, 2011

APPENDIX 9: LETTER OF CONFORMITY AND CALIBRATION INFORMATION OF THE USED THERMAL CAMERA

TROTEC®

Trotec GmbH & Co. KG
Grebbener Straße 7
D-52525 Heinsberg

Edward Muntinga
therapiepraxis muntinga
Alter Fällanderweg 12
CH-8123 Ebmatingen
[redacted]

Heinsberg, 2.12.2012

BETREFF: Konformitätserklärung für EC 060

Sehr geehrter Herr Muntinga,

gemäss Ihrer schriftlichen Anfrage per Email vom 23.11.2012 betreffend einer Konformitätserklärung unserer IR-Kamera EC 060 bestätigen wir Ihnen gerne, dass das Trotec EC 060 den von Ihnen gelieferten Standardvoraussetzungen („internationale Standards definiert von Diadikes und Ring") technisch entspricht.

Alle Messgeräte, darunter auch das EC 060, werden von qualifizierten Trotec-Mitarbeitern bei den Qualitätskontrollen geeicht, sodass die Messgenauigkeit den Produktbeschreibungen entspricht. Genauigkeit wird insbesondere im mittleren Temperaturbereich garantiert (d.h. zwischen -20 °C bis +250 °C), was spezifisch für Ihre Diplomarbeit von Belang sein wird.

Ich hoffe dass ich Ihnen hiermit behilflich sein konnte und wünsche Ihnen eine erfolgreiche Arbeit mit unserem EC 060!

Mit freundlichen Grüssen,

Detlef von der Lieck
Geschäftsführer Trotec.de

TROTEC®
Phone +49 2452 962-400
Fax +49 2452 962-200
info@trotec.com
www.trotec.com

BENEFITS IN PRACTICE:

- Fully radiometric IR cameras "Made in the EU"
- Real-time measurements guarantee high-quality thermal images
- High thermal sensitivity
- Maintenance-free operation using microbolometer technology
- Large, swivel-mounted colour LCD monitor
- Image recording with an image repetition frequency up to 50/60 Hz
- DuoVision function for Picture-in-Picture presentation
- Integrated laser pointer
- In-built digital camera for real-time images
- Built-in photo lamp
- Memory for infrared and real images
- Automatic temperature tracking (Hot/Cold Spot)
- Various measuring functions
- Ergonomic and featherlight
- Robust construction (IP 54)
- Docking station with USB 2.0 port*
- Bluetooth headset for audio recordings (EC 060 V+)

** only for real-time applications*

IR cameras in the EC-Series

First-Class Thermography – Economy-Class Price!

Made in EU

Ground-breaking technology, ground-breaking price

The cutting-edge EC-cameras in the MultiMeasure Professional Series set new standards as far as value for money is concerned.

The maintenance-free, uncooled image sensor has a detector resolution of 160 x 120 measuring spots and a thermal sensitivity of 0.1 °C which enable you to create fully-radiometric thermal images within a temperature range of between -20 °C and +250 °C.

REAL TIME A high image repetition frequency guarantees continuous real-time thermal imaging.

And the mini-USB included in the scope of delivery can quite comfortably save thousands of thermal images.

A variety of integrated measuring functions and the automatic measured value correction function ensure optimum results every single time thus making the thermal imaging cameras in the EC-Series extremely reliable infrared measuring tools.

The interplay between the EC camera and the software included in the scope of delivery allow you to compile comprehensive and conclusive evaluations and reports.

Professional thermography made easy…

The featherweight cameras weigh in at a mere 500 g and fit snugly in the palm of your hand. Yet despite their compact size and low weight they are extremely tough: IP54-protected, 25G shock and 2.5G vibration tested and built to withstand the harshest of conditions.

The practical single-handed control, the ergonomically-arranged keys and the clearly-structured menu not only make the camera extremely user-friendly but also very effective and efficient.

The large 2.5-inch LCD colour display can also be pivoted through an angle of 270° making it possible to create thermal images in hard-to-reach or inaccessible places.

Mains and stress free…

Ther's no need to hunt for a mains point when you want to carry out your measuring application when you've got one of the IR cameras in the EC-Series. The cameras in the EC-Series do not require an external power source because they all run on high-performance Li-ion batteries to guarantee you hours of unimpeded operation and because this type of rechargeable battery does not have a memory effect you can charge them as and when you see fit.

EC as in an "Extra Class" in the field of thermal imaging

Precise real-time measurements, a high thermal sensitivity and a high degree of accuracy, a swivel-mounted colour LCD monitor – this is what you get when you buy an infrared camera in the EC-Series. What you don't get are false promises. The cameras in the EC-Series all come standard-equipped with a variety of functions and features which you would normally only expect to find in a high-end model – with a price tag to match. Should you, however, be looking for something a little more specific: the EC-Series also encompasses two special models - the EC060V and the EC060V+ – for more individual and specialized applications.

A brief overview of the most important differences of models	EC 060	EC 060 V	EC 060 V+
Measuring spots	2	5	10
Isotherm		■	■
Digital camera		■	■
Photo lamp		■	■
DuoVision		■	■
Laser pointer		■	■
Professional analysis			■
Area measurements			■
Bluetooth headset			■
Voice annotations			■
IR real-time via USB 2.0*			■

** in connection with the optionally available software expansion pack*

TRT-KAT-MMEC-WM-02-EN

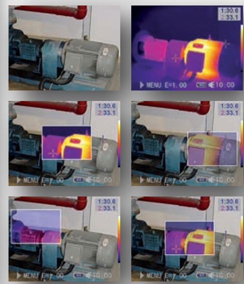
TROTEC®

TEMPERATURE

Technical data		EC060	EC060 V	EC060 V+
Article number		3.110.003.003	3.110.003.004	3.110.003.005
Measuring	Temperature range	-20 °C to +250 °C		
	Accuracy	±2 °C, ± 2% of the measured value		
Image radiometric	Detector type	Focal Plane Array (FPA), uncooled microbolometer		
	Detector resolution	160 x 120 pixels		
	Spectral range	8 to 14 µm		
	Field of Vision (FOV)	20° x 15°		
	Geometric resolution	2.2 mrad		
	Thermal sensitivity	0.1 °C at 30 °C		
	Image repetition frequency	50/60 Hz		
	Focus	manual		
	Min. Focus Distance	0.10 m		
Image visual	Digital photo camera	–	Colour representation 680 x 480 pixels, integrated photo lamp	
	Video norm	PAL		
Image representation	Display	2.5-inch TFT LCD		
	Image display	Pseudo colours, 6 colour palettes		
	Image display options	IR image	IR image, real image, different DuoVision options for combined display of IR and real images	
Measuring functions	Measuring spots	Two movable measuring points (1 x manual, 1 x autom. temperature tracking)	Five movable measuring points (1 x manual, 1 x autom. temperature tracking)	Ten movable measuring points (9 x manual, 1 x autom. temperature tracking)
	Isotherm	–	Yes	
	Professional analysis	–		Yes
	Area measurement	–		5 areas
	Degree of emission	User-defined variably adjustable from 0.01 to 1.0		
	Measurement correction	Automatically on the basis of user-defined input with regard to the surrounding temperature, distance, rel. humidity		
Data storage	Memory medium	Mini-SD card slot		
	Data format radio metric	14 bit radiometric IR format		
	Data format visual	–	CCD	
	Voice recording	–		Voice annotations can be saved with each IR image
Laser	Type	–	Semi-conductor AlGaInP diode laser, 1 mw/635 nm red	
	Classification	–	Class 2	
Power supply	Battery type	Standard, Li-ion; rechargeable, replaceable		
	Operating time	≈ 3.0 h		
	Mains power	8 - 11V DC		
	Energy saving mode	user defined		
Environmental conditions	Operating temperature	-15 °C to +50 °C		
	Storage temperature	-40 °C to +70 °C		
	Relative humidity	10 % to 95 % RH (non-condensing)		
	Protection class	IP 54 IEC 529		
	Shock	25G IEC 68-2-29		
	Vibration	2G IEC 68-2-6		
Physical characteristics	Dimensions	175 x 55 x 160 mm		
	Weight	500 g		
	Tripod mount	1/4-inch - 20		
Interface	PC	–		USB 2.0, Bluetooth
	Video	composite video		
Scope of delivery	Standard lens	20° x 15°		
	Standard equipment	IR camera with standard lens, standard software package, operating instructions, 2GB mini-SD card slot, Li-ion battery, docking station, battery charger, video cable, temperature test certificate; EC060V+ additionally with Bluetooth headset and USB cable for thermographic video recordings in real-time		
	Optional interchangeable lens	38°, 12°, 6.4°, 3.8° lens		
	Optional accessories	Software expansion for real-time IR video recordings (EC060V+), carry case, mains adapter for battery-independent mains supply, further accessories and software packages on request.		

The EC-duo with DuoVision: the EC 060 V and the EC 060 V+

Both the EC 060 V and the EC 060 V+ are equipped with an additional digital camera with a built-in photo lamp designed to shed light on poorly-illuminated and dark areas in order to provide you with crisp, clear photos and an ideal combination consisting of real and thermal images so that you can identify and analyse different problems more quickly and efficiently and find a solution to them.



The infrared camera's patented DuoVision technology enables either infrared or real images to be displayed exclusively or a combination of overlapping images in varying degrees of transparency in freely-selectable areas. This allows any damage or defects to be detected much more easily.

In addition the software DuoVision function allows you to display the overlapped images in varying degrees of intensity. Or to put more bluntly: you decide what you would like to see.

The DuoVision images created using this method provide a far more sophisticated means of analysis and a much more graphic form of documentation.

The Crem de la Crem in the EC-Series: the EC 060 V+

The EC 060 V+ is the flagship product in the EC-Series: it offers the most comprehensive functions and features of all our models and provides you the user with a professional measuring device designed to deliver extremely precise and reliable measuring results in a variety of different applications.

You can voice over videos and attach voice annotations to your thermal images for future reference using the Bluetooth headset included in the scope of delivery.

And the EC 060 V+'s USB 2.0 port allows you to hook your infrared camera up to your computer and use the optionally available software expansion pack to create video recordings and analyses quickly and efficiently.

Trotec | Telemetry | Planning and survey | Temperature | Velocity | Moisture | Multi-function | Tracing and detection | Optical inspection systems | Leak detection

APPENDIX 10: STATISTICAL TABLES

Table: 7. DESCRIPTIVE STATISTICS TABLE OF SAMPLES

Variable	Range	Mean	SD	%
Gender	0/1			
male				46.5
female				53.5
Age	22-60	33.44	9.72	
Complaint (foot, knee, lower leg)	0/1	0.42	0.49	
no				58.1
yes				41.9
Complaint side	-1/3			
right				20.9
none				58.1
left				18.6
both				2.3
Bone fracture	0/1	0.09	0.29	
no				90.7
yes				9.3
Fracture age	0/1	0.09	0.29	
none				90.7
16+ weeks				9.3
Bone fracture side	0/2			
right				7.0
none				90.7
left				2.3
Accident/injuries/operations (AIO)	0/1	0.56	0.50	

Variable	Range	Mean	SD	%
no				44.2
yes				55.8
Accident/injuries/operations (AIO) age	0/6	2.4	2.58	
none				46.5
1-4 months				9.3
5-12 months				7.0
1-2 years				11.6
3-5 years				9.3
6-10 years				7
> 11 years				9.3
Accident/injuries/operations (AIO) side	0/3			
right				23.3
none				46.5
left				25.6
both				4.7
Responsibility	0/1	0.53	0.51	
no				46.5
yes				53.5
Sport per week	0/6	2.11	1.58	
none				16.3
once				16.3
twice				18.6
three times				14.0
four times				11.6
five times				7.0
no answer				16.3

Variable	Range	Mean	SD	%
Inglehart Index	0/3			
0 = pure Postmaterialistism				46.5
1 = rather postmaterialistic				37.2
2 = rather materialistic				2.3
3 = pure Materialism				14.0
Room Temperature [°C]	21-25	23.13	0.97	
Room Humidity [%]	20-45	31.84	5.2	
Intraosseous strain	0/2	-0.09	0.68	
right				27.9
none				53.5
left				18.6
+ Intraosseous: A/P Spring Test	0/3			
normal				53.5
slightly hard				20.9
hard				18.6
very hard				7.0
+ Intraosseous: Torsion Test	0/3			
normal				55.8
slightly hard				30.2
hard				11.6
very hard				2.3
+ Intraosseous: Vitality Test	0/3			
normal				53.5
slightly low				23.3
low				18.6
none				4.7

Variable	Range	Mean	SD	%
Group Identification	0/1			
Case Group				46.5
Control Group				53.5
Note: N = 43				

Table: 8. TEMPERATURE VALUES OF CASE AND CONTROL GROUP

Variable	Case Group		Control Group	
	Mean	SD	Mean	SD
Intraosseous affected leg **(A), max. Temperature**	31.59	0.88		
Healthy leg **(B), max. Temperature**	32.49	1.06		
Intraosseous affected leg **(A), min. Temperature**	26.08	1.46		
Healthy leg **(B), min. Temperature**	26.00	1.34		
Intraosseous affected leg **(A), avg. Temperature**	29.36	0.91		
Healthy leg **(B), avg. Temperature**	29.96	0.78		
Healthy leg **(C), max. Temperature**			33.09	0.82
Healthy leg **(D), max. Temperature**			32.89	0.85
Healthy leg **(C), min. Temperature**			25.27	2.01
Healthy leg **(D), min. Temperature**			24.84	2.50
Healthy leg **(C), avg. Temperature**			30.98	0.00
Healthy leg **(D), avg. Temperature**			30.17	0.82
Healthy legs **(C&D), avg. Temperature**			30.36	0.82
Note: n = 43, Case Group (n = 20), Control Group (n = 23)				

Table: 9. CORRELATIONS

Variables	-1	-2	-3	-4	-5
A/P Spring (1)	1.000	0.411	0.209	-0.056	-.394*
Torsion (2)		1.000	0.267	0.306	-0.295
Vitality (3)			1.000	-0.266	-0.344
Accident/injury/operation (AIO) age (4)				1.000	0.079
Tibia A, average temperature. (5)					1.000
Note-. n = 20; correlation coefficient τ_b (tau-b); ** p < .01, * p < .05					

Table: 10. ANALYSIS OF VARIANCE OF AVERAGE TEMPERATURE FOR ALL FOUR TIBIA GROUPS A, B, C AND D (FOR HYPOTHESIS 1A AND 1B)

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean			
					Minimum		Maximum	
					Lower Bound	Upper Bound	Lower Bound	Upper Bound
A	20	29.3615	0.91291	0.20413	28.9342	29.7888	28.04	31.18
B	20	29.9545	0.77745	0.17384	29.5906	30.3184	28.73	31.30
C&D	46	30.3561	0.81717	0.12048	30.1134	30.5988	28.82	31.47
Total	86	30.0314	0.91595	0.09877	29.8350	30.2278	28.04	31.47
Note: n = 86, case group = 40 tibias (A and B), control group = 46 tibias (C and D)								

Table: 11. ROBUST TEST FOR HYPOTHESIS 1A AND 1B

	Statistic[a]	df1	df2	Sig.
Welch	8.907	2	39.409	0.001
Brown-Forsythe	9.860	2	57.131	0
Note: a. Asymptotically F distributed. n = 86, case group = 40 tibias (A and B), control group = 46 tibias (C and D)				

Table: 12. POST-HOC TEST FOR HYPOTHESIS 1A AND 1B

	(I) Temp. avg.	(J) Temp. avg.	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Dunnett-T3	A	B	-0.59300	0.26813	0.095	-1.2622	0.0762
		C&D	-.99459*	0.23704	0.001	-1.5896	-0.3996
	B	A	0.59300	0.26813	0.095	-0.0762	1.2622
		C&D	-0.40159	0.21151	0.180	-0.9289	0.1258
	C&D	A	.99459*	0.23704	0.001	0.3996	1.5896
		B	0.40159	0.21151	0.180	-0.1258	0.9289
Games-Howell	A	B	-0.59300	0.26813	0.082	-1.2476	0.0616
		C&D	-.99459*	0.23704	0.001	-1.5763	-0.4128
	B	A	0.59300	0.26813	0.082	-0.0616	1.2476
		C&D	-0.40159	0.21151	0.153	-0.9175	0.1143
	C&D	A	.99459*	0.23704	0.001	0.4128	1.5763
		B	0.40159	0.21151	0.153	-0.1143	0.9175
*. The mean difference is significant at the 0.05 level.							
Note: n = 86, case group = 40 tibias (A and B); control group = 46 tibias (C and D)							

Table: 13. TEMPERATURE AVERAGE (B:A) TO (C:D), FOR HYPOTHESIS 2

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	9.840	1	9.840	14.648	0.000
Within Groups	27.544	41	0.672		
Total	37.384	42			

Table: 14. TEST FOR HOMOGENEITY OF VARIANCES FOR TEMPERATURE AVERAGE (B:A) TO (C:D), FOR HYPOTHESIS 2

Levene Statistic	df1	df2	Sig.
3.148	1	41	0.083

Table: 15. ROBUST TESTS OF EQUALITY OF MEANS, FOR HYPOTHESIS 2

Temperature average (B:A) to (C:D)				
	Statistic[a]	df1	df2	Sig.
Brown-Forsythe	15.691	1	36.430	0.000
a. Asymptotically F distributed.				

APPENDIX 11: LETTER OF STATISTICIAN

Oliva & Co. GmbH
Dr. phil. Carl Oliva
Dr. phil. Cornelia Hüttenmoser Oliva
Postfach 6360
CH-8050 Zürich-Oerlikon

Edward Muntinga
Forchstrasse 99p
8132 Egg b. ZH

30.11.2012

Dear Madams, Dear Sirs,

I hereby confirm that I performed all statistical coaching and analysis of the thesis research project *„Thermographic Skin Measurement and osteopathic Palpation of tibial Intraosseous Strains in Adults - a comparative Pilot Study"* written by Edward Muntinga.

I hope that Mr.Muntinga's thesis will be approved by the jury of the Swiss International College of Osteopathy in June 2013.

Best regards,

Cornelia Hüttenmoser
(document valid without signature)

APPENDIX 12: DATA MATRIX

Subject No.	GENDER	AGE	Complaints Knee/Foot/ Ankle?	Yes, left/right	Fracture Tibia	Yes, 0-16 Weeks / 16+ Weeks	Yes, left/right
	male = 0, female = 1	years	no (0), yes (1)	eft (1), right (-1), none (0), both sides (3	no (0), yes (1)	none= 0, 0-16 wo (1), 16+ (-1)	left (1), right (-1), none (0)
2	1	34	1	1	0	0	0
6	0	27	0	0	0	0	0
7	1	60	1	-1	1	-1	-1
8	0	24	0	0	0	0	0
9	0	39	1	1	0	0	0
10	1	35	1	-1	0	0	0
12	0	47	1	-1	0	0	0
13	1	31	1	1	0	0	0
14	0	22	1	1	0	0	0
15	1	28	1	-1	0	0	0
16	0	23	1	1	0	0	0
17	1	24	1	-1	0	0	0
18	0	22	0	0	0	0	0
19	1	24	0	0	0	0	0
20	0	23	1	-1	0	0	0
21	1	34	1	-1	0	0	0
22	0	45	0	0	0	0	0
23	0	32	1	1	0	0	0
24	0	23	1	-1	0	0	0
25	0	31	1	-1	0	0	0
1	1	45	1	1	0	0	0
3	1	22	0	0	0	0	0
4	1	27	1	3	0	0	0
5	1	28	0	0	0	0	0
11	1	34	0	0	1	-1	-1
26	0	45	0	0	0	0	0
27	0	43	0	0	0	0	0
28	1	42	0	0	0	0	0
29	0	54	0	0	0	0	0
30	1	23	0	0	0	0	0
31	1	26	0	0	0	0	0
32	0	29	0	0	0	0	0
33	0	28	1	1	1	-1	1
34	0	26	0	0	0	0	0
35	1	54	0	0	0	0	0
36	0	34	0	0	0	0	0
37	1	46	0	0	0	0	0
38	1	37	0	0	0	0	0
39	0	35	0	0	0	0	0
40	1	32	0	0	0	0	0
41	1	31	0	0	1	-1	-1
42	1	30	0	0	0	0	0
43	1	39	0	0	0	0	0

Subject No.	Accidents/Injuries/ Operations	yes, 0-3w(1)/1-4mt(2)/5-12mt(3)/1-2j(4)/ 3-5j(5)/6-10j(6)/11+j(7), none = 0	Yes, left/right	Responsible?	Frequency Sport/Week	INGLEHART Index	Toom Temp Celsius	Room Humidity
	no (0) / yes (1)		left (1)/ right (-1), 0=none, 3=both sides	0=no, 1=yes	0/1/2/3/4/5/6/7/8	0/1/2/3	Degrees Celsius	%
2	1	4	1	1	5	1	24	35
6	0	0	0	0	2	0	21	31
7	1	2	-1	1	3	0	24	33
8	1	7	1	1	2	0	23	32
9	1	7	1	1	2	1	25	22
10	1	7	-1	1	2	1	23	20
12	1	6	-1	1	1	0	24.5	30
13	1	4	1	1	0	1	22	45
14	1	2	1	1	3	0	24	42
15	1	5	-1	1	0	1	24,3	40
16	1	2	1	1	1	3	23	34
17	1	3	-1	1	4	1	23.5	26
18	0	0	0	0	4	1	24	34
19	1	5	1	1	5	0	24.5	27
20	1	4	-1	1	3	1	22	30
21	1	2	-1	1	3	1	23	34
22	1	3	1	1	5	3	23.5	35
23	1	5	1	1	1	1	24	37
24	1	4	-1	1	2	0	22.5	32
25	1	7	1	1	3,5	1	23	31
1	0	0	0	0	2,5	3	22	29
3	1	5	-1	1	0	3	23	24
4	1	4	3	1	3	0	22	32
5	0	0	0	0	2,5	0	21	32
11	1	6	3	1	4	1	24.5	25
26	0	0	0	0	3,5	1	23	26
27	0	0	0	0	2,5	1	24	34
28	1	0	0	0	4	0	24.5	35
29	0	0	0	0	1	0	22	32
30	0	0	0	0	1	0	23	29
31	0	0	0	0	2,5	0	22.5	28
32	0	0	0	0	2	0	22.5	26
33	1	6	1	1	3	0	23	35
34	0	0	0	0	2	3	22	37
35	0	0	0	0	4	2	22.5	40
36	0	0	0	0	1	0	24	36
37	0	0	0	0	0	0	23.5	35
38	0	0	0	0	0	3	24	29
39	0	0	0	0	2,5	0	23.5	28
40	0	0	0	0	2	1	22.5	26
41	1	3	-1	1	1	1	23	36
42	0	0	0	0	0	0	24	33
43	0	0	0	0	0	0	22	32

Subject No.	Group Identification	Intraosseous + right/left/none	Area1: A/P Spring	Area1: Torsion	Area1: Vitality
	1= Case Group, 2= Control Group	none (0), left (1), right (-1)	0=normal/1/2/3=very hard		0=normal/1/2/3=very low
2	1		1	1	1
6	1	-1	1	1	1
7	1	-1	1	1	2
8	1	-1	1	1	1
9	1	-1	1	0	1
10	1	-1	1	2	1
12	1	-1	1	1	1
13	1	1	2	2	3
14	1	1	2	1	2
15	1	-1	2	2	2
16	1	-1	1	1	3
17	1	-1	2	1	2
18	1	1	2	1	1
19	1	1	3	2	2
20	1	-1	2	1	1
21	1	-1	3	1	2
22	1	1	2	1	1
23	1	1	2	3	2
24	1	-1	1	1	2
25	1	1	3	2	1
1	2	0	0	0	0
3	2	0	0	0	0
4	2	0	0	0	0
5	2	0	0	0	0
11	2	0	0	0	0
26	2	0	0	0	0
27	2	0	0	0	0
28	2	0	0	0	0
29	2	0	0	0	0
30	2	0	0	0	0
31	2	0	0	0	0
32	2	0	0	0	0
33	2	0	0	0	0
34	2	0	0	0	0
35	2	0	0	0	0
36	2	0	0	0	0
37	2	0	0	0	0
38	2	0	0	0	0
39	2	0	0	0	0
40	2	0	0	0	0
41	2	0	0	0	0
42	2	0	0	0	0
43	2	0	0	0	0

Subject No.	Right Temp.max	Right Temp.min.	Right Temp.avg.	Left Temp.max	Left Temp.min.	Left Temp.avg.
	Degrees Celsius					
2	32.95	25.78	30.24	31.76	26.57	29.41
6	32.43	28.81	31.03	32.40	28.91	31.30
7	33.04	26.95	30.75	33.10	27.23	31.19
8	32.61	28.53	31.18	32.46	27.60	31.21
9	32.52	26.72	30.58	31.80	26.69	30.08
10	31.65	25.86	29.11	32.04	25.37	29.14
12	31.17	26.17	29.77	31.09	26.03	29.35
13	33.04	27.75	30.27	32.00	26.99	29.72
14	30.73	26.52	28.73	30.63	26.41	28.35
15	30.76	24.98	28.04	33.35	24.76	29.13
16	31.46	26.03	29.07	32.67	26.98	29.98
17	30.73	25.89	28.89	33.14	24.95	29.34
18	31.98	26.13	29.15	31.76	25.99	28.87
19	34.08	24.96	30.98	31.26	23.86	29.15
20	33.56	21.76	29.30	32.75	26.01	30.45
21	30.56	25.97	28.68	31.79	24.05	29.67
22	33.72	24.67	29.89	30.62	26.01	29.54
23	29.94	26.98	29.12	31.56	25.98	28.27
24	30.75	26.15	28.45	33.95	24.67	29.76
25	32.87	23.89	30.11	30.92	25.99	29.07
1	33.87	24.98	30.98	31.94	25.09	29.87
3	34.12	27.96	31.38	33.82	27.51	31.47
4	31.97	25.22	29.06	31.85	20.65	28.82
5	32.91	28.01	30.91	32.55	27.32	30.58
11	31.96	27.74	30.02	31.57	27.05	29.54
26	33.67	24.87	31.23	33.76	20.97	28.99
27	32.89	23.98	31.09	32.98	21.67	29.96
28	31.99	26.56	30.97	31.07	23.59	30.08
29	34.01	23.39	29.98	33.10	27.85	30.17
30	33.87	25.68	30.78	32.98	24.78	29.08
31	33.09	20.99	31.22	34.02	27.49	31.10
32	34.11	24.43	31.01	33.90	23.09	30.79
33	32.56	24.69	28.99	33.06	28.00	30.18
34	32.91	27.87	28.83	32.67	27.01	29.93
35	31.97	26.09	30.67	32.04	26.07	31.06
36	34.08	25.01	31.22	33.79	21.99	31.29
37	33.47	25.85	29.95	32.98	26.86	31.01
38	33.82	23.56	30.09	33.45	27.04	29.06
39	32.08	22.18	31.05	32.69	23.85	29.87
40	32.79	27.03	31.20	31.84	26.48	28.99
41	31.85	27.96	29.78	33.85	21.90	30.19
42	33.94	21.99	30.87	33.67	22.78	31.13
43	33.15	25.07	31.12	32.78	22.46	30.82

APPENDIX 13: REQUEST FOR CHANGING THE THESIS TITLE

As discussed personally with Philippe Druelle D.O. (2012) on the fifth thesis day in Hertenstein, we decided to change the thesis title. See below the email written on 22.11.2012:

Gmail by Google

Edward Muntinga <edwa[redacted]

Request for changing thesis title
2 Nachrichten

[redacted] 2012 11:18

Note to Isabel: please forward to Marie Colford and Paul Wagner, thank you!

Dear Julie, Dear Marie and Paul,

I hope you are doing well, healthy and sound! After a discussion with Philippe Druelle today (thesis day) about my thesis, we decided to change the title of the thesis accordingly:

OLD:
Detection of Intraosseous Strains on the adult tibial bone with thermography - a pilot study."

NEW*:*
A comparative pilot study between thermographic skin measurement and osteopathic palpation of tibial intraosseous strains in adults.
or I prefer:
Thermographic skin measurement and osteopathic palpation of tibial intraosseous strains in adults - a comparative pilot study.

I would like to ask permission for this change, since the new title shows the nature of my work more accurate.

Thank you very much for your agreement and support.

Have a great day,

Edward Muntinga, CO SICO, CST, PT
Switzerland

[redacted] 2012 15:31

a

See below the answer by email form Julie Brown D.O., received the same day:

Hi Ed,

I like, and support, this change. It is more precise and very clear. I also prefer the bolded option.

How is it all going?

Julie

Sent from my iPhone

On 2012-11-22, at 3:18 AM, Edward Muntinga <[redacted] wrote:

> **Note to Isabel: please forward to Marie Colford and Paul Wagner**, thank you!
>
> Dear Julie, Dear Marie and Paul,
>
> I hope you are doing well, healthy and sound! After a discussion with Philippe Druelle today (thesis day) about my thesis, we decided to change the title of the thesis accordingly:
>
> **OLD**:
> *Detection of Intraosseous Strains on the adult tibial bone with thermography - a pilot study."*
>
> **NEW**:
> *A comparative pilot study between thermographic skin measurement and osteopathic palpation of tibial intraosseous strains in adults.*
> *or I prefer:*
> ***Thermographic skin measurement and osteopathic palpation of tibial intraosseous strains in adults - a comparative pilot study.***
>
> I would like to ask permission for this change, since the new title shows the nature of my work more accurate.
>
> Thank you very much for your agreement and support.
>
> Have a great day,
>
> Edward Muntinga, CO SICO, CST, PT
> Switzerland
> [redacted]
>
> --
> ....
> "motion is THE expression of life"
>
> *Edward Muntinga, Osteopath SICO, CST, PT*
> *www.muntinga.ch*