Unilateral cross-bite and possible interrelations with the loading of the foot in the stance phase

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by

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DECLARATION

Hereby I declare that I have written the present master thesis on my own.
I have clearly marked as quotes all parts of the text that I have copied literally or rephrased from published or unpublished works of other authors.
All sources and references I have used in writing this thesis are listed in the bibliography. No thesis with the same content was submitted to any other examination board before.

Date: **Signature:**

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Preface

When my son Simon was diagnosed with bilateral pes valgus and two years later with a cross-bite, my interest in the topic: "Unilateral cross-bite and possible interrelations with the loading of the foot in the stance phase" was raised. Among the patients in my osteopathic practice I treat a number of children who come to see me because of problems related to the position of their feet. In many cases the case history shows that these children often also have problems with a faulty position of their teeth. Equally, I can often observe that children with problems of malocclusion load their feet in a way that deviates from the physiological loading pattern. Could it be that these problems are interrelated? I could not let go of this question anymore.

I started to research the subject. In the book "Praxis der Kranialen Osteopathie" (Practice of Cranial Osteopathy, Liem 2004) and in the courses during my osteopathic training it was repeatedly maintained that there was a connection between the occlusion and shoulder and pelvis asymmetries or scolioses…. However, I only found a few isolated scientific studies regarding this topic. Also the private lecturer Dr. Mathias Fink (2007), author of several publications on very similar topics, confirmed my assumption. In his article on functional relations of the cranio-mandibular system with the cervical and lumbar/pelvic/hip regions Fink (2003) points out that these relations are scientifically disputed and that they are mainly postulated by osteopaths. However, he suggested that it would be interesting to carry out a study with regard to possible connections between occlusion and the feet, which reinforced my decision to carry out a research project on the subject.

Dedicated to:

My three children

And all other children because they are our future

Thank you for your support!

Primar Dr. Bochdansky Thomas

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All children and their parents who participated in the study

The staff of the Department for Physical Medicine and Rehabilitation at the regional hospital Rankweil

1. Introduction

The main research question of this study is: Can interrelations between a unilateral cross-bite and the loading of the foot in the stance phase be identified?

Research projects where the test persons' occlusion is temporarily altered artificially have already been carried out. Fink et. al. (2003), for instance, evaluates the correlation of artificial changes in occlusion and their influence on the lumbar/pelvis/hip regions.

Several studies regarding the interrelations of bite patterns and the spine, head, pelvis or legs have been carried out in recent years. A literature research with the key words: Beinlänge (leg length), Beckenschiefstand (pelvic asymmetry), Wirbelsäulenbefunde (spine findings), Kopfhaltung (head posture) as well as a manual search of evidence-based dentistry by Hanke et al. (2007) resulted in 359 articles on interrelations between bite anomalies and findings in the regions of the legs, pelvis, head, spine and teeth. Among these 359 articles 35 dealt with interrelations between occlusion and leg length differences.

The results of the evaluation of these interrelations between occlusion and leg length differences are quite varied. Korbmacher et al. (2007), for instance, look at an orthopaedic patient cohort of 240 children aged 3-10 years. All children display an asymmetry of the upper cervical spine (Dens axis). 55 children (23%) among them have a unilateral cross-bite. Another 55 children (23%) have a symmetrical bite pattern. The statistical analysis shows that compared with the children who have a symmetrical occlusion the children with the unilateral cross-bite more often have a leg length difference (p=0.002), a pelvic asymmetry (p=0.007) or shoulder asymmetry (p=0.004).

However, another study by Michelotti et al. (2007) cannot identify a statistical correlation between a unilateral cross-bite and a difference in the leg length. In this study 1159 children with an average age of 12 years are examined with regard to a difference in their leg length. 120 children (10.3%) have a leg length difference and 142 children (12.2%) have a unilateral cross-bite. However, the authors of the study do not describe a correlation between the cross-bite and the leg length difference.

Studies regarding the correlation between malocclusion and the feet are very rare to find. Valentino et al. (2002) look at the artificial change of the position of the foot with synthetic shoe inlays and the influence on the activity of the Musculus (M.) Masseter and M. Temporalis among ten students at the age of 20. By means of electromyography (EMG) the author takes measurements during a temporarily produced valgus-position of the arch of the right foot. This causes a hypertonicity of the chewing muscles on the right side and a reduction of the basic muscle tone of the chewing muscles on the left side.

Also the study of Lippold et al. (2000) involving 50 patients aged between 4 and 55 years shows a statistically significant correlation between jaw asymmetries and orthopaedic findings. Based on his study results Lippold recognizes an indication to treat these patients with an interdisciplinary approach.

The results of the above mentioned studies are quite contradictory regarding the correlation between bite anomalies and the feet. This is the reason why there are still many critical voices (Michelotti et al., 2007; Fink et al., 2003) who doubt that such correlations can be proven:

> *"Über einen Einfluss einer Veränderung des stomatognathen Systems auf andere Körperregionen, auch außerhalb des kraniozervikalen Systems, liegen bisher kaum gesicherte wissenschaftliche Erkenntnisse vor, wenngleich diese Zusammenhänge vor allem von Vertretern der Osteopathie postuliert werden" (Fink et al. 2003, p.476).*

> *"The influence of changes in the stomatognathic system on other body regions also outside the cranio-cervical system is hardly tried and proven by scientific facts, even though these correlations are postulated in particular by representatives of osteopathy." (Fink et al. 2003, p.476).*

Fink (2003) mentions the stomatognathic system which comprises the entire chewing apparatus. Its connections with the junction between the occiput and cervical spine will be explained in detail in Chapter 2.1.1.

The osteopathic profession refers to five basic principles:

- Life is motion
- Structure governs function
- The body works as a unit
- The law of the artery
- Self-healing mechanisms

These basic principles were originally devised by the founder of osteopathy Andrew Taylor Still (1828-1917) and are taught by teachers like Bernard Ligner and Raphael Van Assche (1993) at the Wiener Schule für Osteopathie (WSO, Vienna School of Osteopathy). From an osteopathic perspective it is in particular the principle that the body works as a unit which indicates that a unilateral cross-bite could have an influence on the whole body.

The present study wants to find out whether a correlation between malocclusion and the loading of the feet can be observed in children who have a diagnosed ‘unilateral cross-bite’. If such correlations between the chewing apparatus and the loading of the feet can be established, this would confirm one of the basic principles of osteopathy: “The body works as a unit”. In addition, a scientific proof of correlations between bite anomalies and problems of the feet could improve an interdisciplinary cooperation in treating such problems, i.e. cooperation between osteopaths and orthodontists, and thus achieve better results for the patients. The desire of an interdisciplinary cooperation in the case of cranio-mandibular dysfunctions is also formulated by Schupp (2003), who is one of the co-authors of the “Manual on Paediatric-Orthodontic Evaluation” published by the Professional Association of German Orthodontists (“Leitfadens zur kinderärztlich-kieferorthopädischen Untersuchung des Berufsverbandes Deutscher Kieferorthopäden”). In his article he even mentions examples of successful cooperation with osteopaths.

Therefore the aim of the present study is to evaluate the above-mentioned possible interrelations in order to confirm the following hypothesis: In the case of the diagnosed bite anomaly “unilateral cross-bite” correlations with alterations of the loading of the foot during the stance phase can be observed.

2. Background

To facilitate the understanding of the study and the classification of the bite anomaly "unilateral cross-bite" and its possible influences on the foot fundamental issues will be explained in the following sections. It is assumed that the reader has a good knowledge of anatomy and physiology.

2.1 Occlusion

Two models of occlusion classifications will be presented because they form the basis for the inclusion and exclusion criteria of the study and control groups in the present study.

The classifications of occlusion that are generally used in Austria are the classification according to Angle (1907) and the classification according to Kantorowicz (1929) and Korkhaus (1928). Towards the end of the 19th century Angle developed a classification of bite anomalies following morphological aspects. The point of reference for the classification of the anomaly is the lower jaw based on the assumption that the mandible is the movable part of the temporo-mandibular joint (TMJ). According to Clausnitzer (2002) Angle differentiates between three main groups:

Angel Class I (neutral bite): the mesiobuccal cusp of the upper first molar rests in the groove between the mesiobuccal and mediobuccal cusps of the mandibular first molar (cf. Figure 1) (Rakosi&Jonas, 1989)

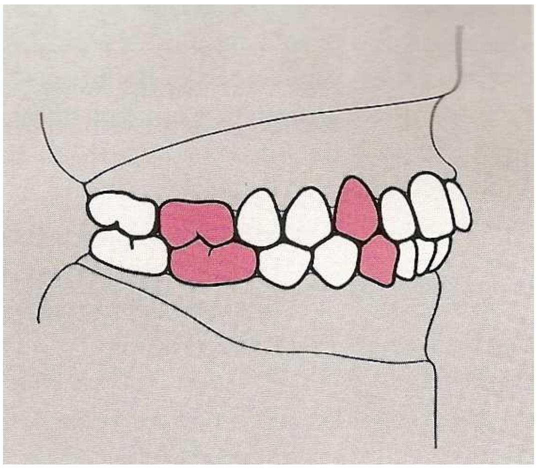


Figure 1. Angel Class I (Rakosi&Jonas, 1989)

Angel Class II/1 (retrognathism, overbite, mandibular retrusion with anterior maxillary teeth protruded): The mandibula is shifted distally in relation to the maxilla. Figure 2 illustrates this bite anomaly with a schematic presentation of a mandibular retrusion by the width of one premolar at the 3rd and 6th teeth. (Rakosi&Jonas, 1989).

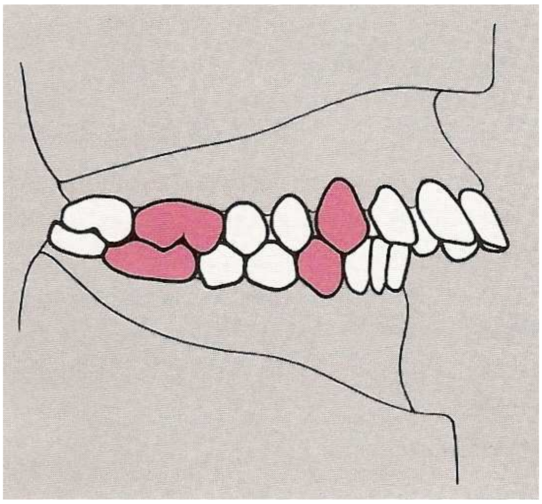


Figure 2. Angel Class II/1 (Rakosi&Jonas, 1989)

Angel Class II/2 (mandibular retrusion with central maxillary teeth retroclined = deep bite or “covered bite” with mandibular retrusion). Figure 3 is a schematic presentation of a deep bite with mandibular retrusion by the width of one premolar (Rakosi& Jonas, 1989).

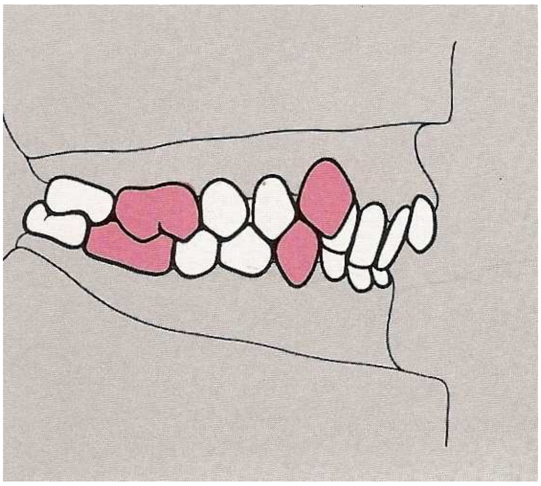


Figure 3. Angel Class II/2 (Rakosi&Jonas, 1989)

Angel Class III (prognathism, underbite or negative overjet; mesial occlusion): The lower jaw is shifted mesially in relation to the upper jaw. Figure 4 is a schematic presentation of a frontal cross-bite with mesial occlusion by the width of one premolar (Rakosi&Jonas, 1989).

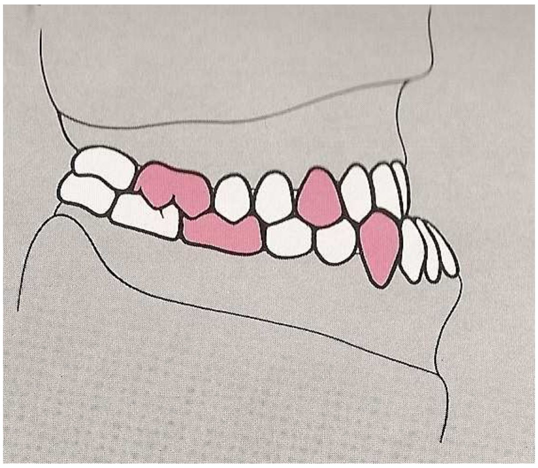


Figure 4. Angel Class III (Rakosi&Jonas, 1989)

In 1926 Kantorowicz and Korkhaus developed a biogenetic classification, which was later revised by Reichenbach and Brückl (1962, quoted according to Clausnitzer, 2002, p.34).
They differentiate between narrow jaw, cross-bite, prognathism, deep bite, open bite, the consequence of premature loss of teeth and other conditional anomalies.

The following section will focus on the definition of the cross-bite, one of the bite anomalies according to the classification of Kantorowicz and Korkhaus. It is important for the understanding of the study to understand the nature of a cross-bite. A cross-bite (cf. Figure 5) is misalignment of the teeth in the lateral region of the jaws. Therefore this kind of bite anomaly is also called lateral malocclusion. In the case of a cross-bite the buccal cusps of the upper lateral teeth close down outside the buccal cusps of the lower teeth. This can be the case on one side or on both sides. If the cross-bite can only be observed on one side, the literature uses the term unilateral cross-bite (Clausnitzer, 2002; Harzer, 1999).

Figure 5. Cross-bite (http://invisible-braces.net/CrossBites.html, 2008)

2.1.1 Occlusion – TMJ – Craniomandibular System

The position of the mandible/temporo-mandibular joint (TMJ) in relation to the head is determined in the closed bite by means of the cusps/grooves relief of the teeth (occlusion). The position of the TMJ has an influence on the ventral and dorsal supporting and locomotor systems in the body. Clinically the TMJ has repercussions like the head-neck-joint even though it is counted among the peripheral joints (Schupp, 2005).

The two most superior cervical segments (atlas and axis) form the lower head-neck joint, also called atlanto-axial joint (Articulatio atlantoaxialis). In the upper head-neck joint the atlas also articulates with the condyles of the occiput (Articulatio atlantooccpitalis) and thus carries the head. Caudally, the axis is relatively tightly linked with the third cervical vertebra, while the articulation between the third and fourth cervical vertebrae is quite mobile. Sometimes also the C2/C3 joint is counted among the head-neck-joints. The cervical spine is divided into the upper cervical spine (C1-C2/C3) and the lower cervical spine (C4-C7). However, the chain of articulations does not end at the upper head-neck-joint (atlanto-occipital joint) but continues up to the TMJ (Articulatio temporomandibularis), for the movements of the TMJ have to be subtly balanced by the movements of the head-neck joint. The proprioceptive innervation of the neck muscles is responsible for perceiving the position of the head in relation to the body. Thus it plays an essential role for controlling the head and eye movements and for maintaining balance, as well as for the body's orientation in three-dimensional space. In addition, the neck muscles have to be seen in relation to the prevertebral muscles, the suprahyoidal and infrahyoidal muscles and the muscles of mastication; not to forget the muscles of the tongue, pharynx and larynx. The majority of these muscles have a direct influence on the lower jaw and thus on the TMJ and occlusion (Neuhuber, 2007).

An examination of 28 children (14 of whom with a unilateral cross-bite) confirms the interrelation between occlusion and the loading of the feet if the TMJ is regarded as head-neck-joint as described by Schupp (2005). The results of this study show a correlation between a unilateral cross-bite and the inclination of the head to the side of the unilateral cross-bite (Bevillaqua-Grossi et al., 2008).
If the inclined position of the head due to the cross-bite is conveyed onto the foot by means of gravity lines (cf. Chapter 2.3) the loading of the feet should be asymmetrical.

The TMJ is the central element in the interrelation between the occlusion (alignment of the teeth of the upper and lower jaws when brought together) and the body posture. The position of the two osseous parts of the joint (Fossa mandibularis of the Os temporale and the Caput mandibulae of the mandible) is determined by the position of the teeth of the upper and lower jaw in relation to each other. In an ideal occlusion the two parts of the joint have a position in relation to each other that is ideally centred. Any form of malocclusion thus has a direct influence on the interaction of the two elements of the articulation. Vice versa also dysfunctions of the articulation have an influence on the occlusion (Honikel, 2007).

The conceptual model of Wühr (2008) describes the cranial bones as continuation of the spine in the region of the head. According to Wühr the lower jaw is the superior end of the spine. Thus the lower jaw can introduce a scoliosis at the upper end of the spine in the case of abnormal occlusion, which then translates onto the whole body via the facial system.

In a study involving 106 test persons Cattaneo et al. (2005) examine the birth process and its influence on the position of the teeth. 24 test persons have an Angel Class I occlusion and 82 test persons can be classified as Angel Class II or III or other forms of malocclusion. In the case of 82 test persons the birth process was not normal (very fast or long delivery, Caesarean); only 10 of these test persons a correct occlusion (Angel Class I), while among 72 of them a form of malocclusion could be observed.

2.2 The Foot

The “normal foot” can be defined through its bony form, its ligamentous and capsular structures as well as the muscle function and functional load during weight-bearing (Döderlein et al., 2002).

In the present study the functional load of the foot during weight-bearing in the stance phase is evaluated.

The functional load is measured with a force plate where a specific pressure pattern of the foot can be observed. These pressure patterns help to recognize differences between the study and control groups (Bosch&Rosenbaum, 2006).

As a child starts walking the pressure pattern changes with the child’s development. Thus the level of development of the pressure pattern should be the same in all children. The following section will describe the development of the foot pressure pattern:

The development of the pressure pattern of a child’s foot starts when the child starts to walk on his/her own and continues quite rapidly within the first two years after the child started to walk (Volpon, 1994).
The pressure in the region of the lateral forefoot decreases while the pressure in the region of the medial and central forefoot increases with increasing age. In the region of the heel the pressure decreases also, while in the region of the halux an increase of the pressure can be observed with increasing age. Peak pressure, maximum force and contact times in the region of the midfoot are constant in the compared age groups. These are the results of an evaluation among 141 children aged 5-15 years (Nielsen et al. 2003).

However, Sutherland et al. (1988) agree that the foot is fully developed by the age of six and corresponds to the foot of an adult person. This is the result of a study among 186 children between the ages of 1 and 7 years (Sutherland et al 1988).
Bosch and Rosenbaum (2006) as well as Putti et al. (2009) did not find any gender-specific differences regarding the pressure pattern of the foot roll-over between boys and girls.

In the context of this study it is important that the pressure pattern of the foot of all evaluated children is fully developed so that no age-dependent changes in the loading of the foot and thus development-related changes in the pressure pattern occur. Based on the information from the available literature the minimum age of the children in this study was thus set at seven years of age. No difference was made between boys and girls. The main focus lies on the evaluation of the symmetry of the pressure patterns of the left and right foot.

2.2.1 Gait cycle – Stance phase

The gait cycle is defined as the period between the moment when one foot initially contacts the ground and the next initial ground contact of the same foot (cf. Figure 6). Every gait cycle consists of a stance phase and a swing phase. The stance phase is the period of the gait cycle where the foot has contact with the ground. It starts with the heel contact on the ground. The swing phase is the period where the foot is in the air and the leg is swung forward. The swing phase starts when the foot leaves the ground and the forward swing is initiated (Götz-Neumann, 2006).

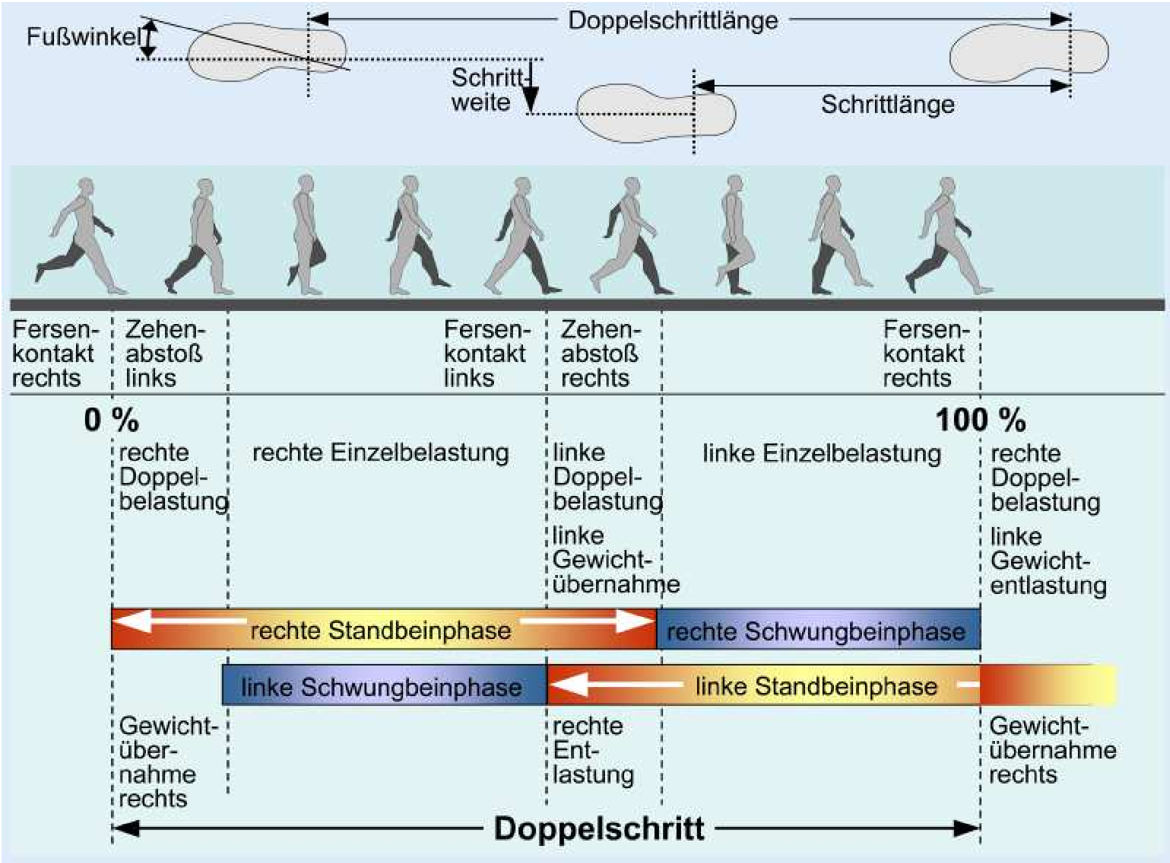


Figure 6. Phases and definitions of the gait cycle (Mittelmeier&Rosenbaum, 2005)

The stance phase can be further divided into five phases:

1st Phase (initial contact): This is the moment when the heel first touches the ground.

2nd Phase (shock absorber phase): This phase starts with the initial ground contact and ends with the lifting of the contra-lateral leg.

3rd Phase (mid-stance): This phase starts with the lifting of the contra-lateral foot (toe-off) and ends when the heel of the standing leg is lifted off the ground.

4th Phase (terminal stance): This phase begins when the heel of the reference leg is lifted off the ground and ends with the initial ground contact of the contra-lateral foot.

5th Phase (pre-swing): This phase begins with the initial ground contact of the contra-lateral foot and ends with the lifting of the standing leg (toe-off).

The swing phase is divided into three phases:

1st Phase: This phase starts with the lifting of the reference leg (toe-off).

2nd Phase (mid-swing): This phase starts when the tibia of the standing leg crosses the tibia of the reference leg in the sagittal plane. It ends when the tibia of the reference leg (swing leg) is vertical in relation to the ground.

3rd Phase: This phase starts when the tibia of the reference leg is vertical to the ground and ends when the foot of the reference leg touches the ground (Götz-Neumann, 2006).

The foot contacts the ground with three areas usually in the following order: heel, whole sole of the foot (heel and forefoot) and forefoot. The first metatarsal bone is the element of the forefoot that has the final contact with the ground, while the body weight is shifted onto the contra-lateral leg (cf. Figure 7). In the beginning the foot only has contact with the posterior edge of the heel but the contact is immediately rolled-over to the centre of the heel. Later also the forefoot has contact with the ground so that the whole foot serves as base of support. How the forefoot contacts the ground differs from individual to individual. In 71% of the cases the fifth metatarsal head (MT5) touches the ground. In less than 1% of the cases there is no contact of the whole sole of the foot. As soon as the heel is lifted off the ground only the forefoot serves as base of support. Usually the toes are the last to leave the ground. It is considered normal when the first metatarsal head and the toes are lifted at the same time (Perry, 2003).

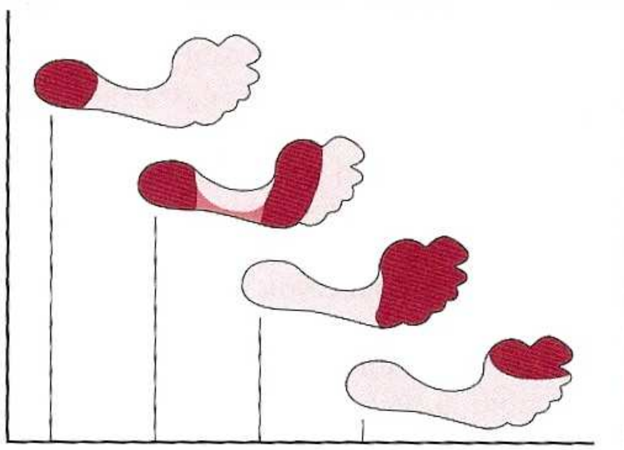


Figure 7. Ground contact pattern according to Perry (Perry, 2003)

When the weight is shifted onto the standing leg, the tissues of the sole of the foot are subject to a certain amount of pressure. The amount of pressure depends on the force that acts upon the foot and how much surface contact the sole of the foot has. The heel is loaded in two phases. First, a very small posterior and lateral zone of the heel is loaded, which absorbs the first quickly falling load of the body weight. Thus the pressure load of the foot is the highest in this region (Cavanagh, 1980).

2.3 Interrelations Occlusion - Foot

In his model the osteopath Littlejohn describes a gravity line from the mandibular symphysis (Symphysis menti) to the pubic symphysis (Symphysis pubis). Littlejohn also describes functional triangles in the body, which relate the TMJ with the other structures in the body (cf. Figure 8). He draws a line from the anterior edge of the Foramen magnum to the coccyx. This line is balanced by two additional lines running from the posterior border of the Foramen magnum to the acetabulum on each side, crossing the first line at the level of the fourth thoracic vertebra (D4). This produces two triangles: one above and one below the third rib and D4 (centre of gravity). Ventrally to these lines Littlejohn describes a fourth functional line between the Symphysis mandibulae and the Symphysis pubis.

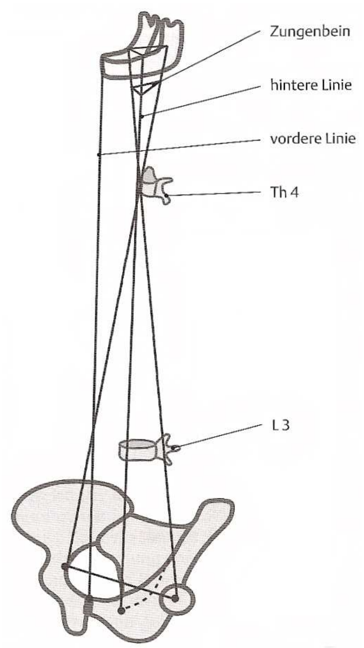


Figure 8. Polygon of forces according to Littlejohn (Liem, 2003)

The function of the triangles: They support the vertebral column and the organs. The superior triangle includes the articulations related to the Foramen magnum. It is regarded as the foundation for the skull, which is balanced on D4. Rotations of the head have an influence all the way down to D4. An imbalance of the hyoid bone and its muscular interconnections has an influence on the function of the superior triangle.

The lower triangle ensures a good function of the abdominal region due to the rhythmic activity of the thorax. Normal pelvic statics (base of the triangle) is the precondition for a good support of the abdominal tone (Liem, 2003).

A conceptual model that is used in osteopathy is the model of postural patterns according to Hall and Wernham (1965, quoted according to Liem, 2003, p.298-300), who described the posture from head to toes when the line of gravity is shifted. In a normal situation the gravity line runs from the Dens axis through the promontorium of the sacrum, through the centre of the hip and knee down to the Articulatio calcaneocuboidea. This gravity line is the result of the interaction of forces that act upon the body and keep it upright. The head is in line with the centre of the pelvis and the shoulder girdle is parallel to the pelvic girdle. The anterior line runs from the tip of the chin to the pubic symphysis. It runs parallel to the line of gravity and perpendicular to the pubic line. It is the result of the thoracic and abdominal tensions. The thoracic and abdominal pressures are normal. If the line of gravity is shifted anteriorly or posteriorly, dysbalances in the whole body can occur (Liem 2003).

A study among 55 children aged between three and ten years (Korbmacher et al., 2007) produced the statistically significant results that children with a cross-bite more often display shoulder asymmetries ($p=0.004$) or pelvis asymmetries ($p=0.007$) in comparison with children with a normal occlusion. Also differences regarding the incidence of functional leg length differences ($p=0.002$) and scolioses ($p=0.04$) could be observed.

EMG measurements that were carried out among ten young test persons (average age: 20 years), male and female, show the following results: A synthetic shoe inlay which produced a temporary valgus-position of the arch of the right foot leads to a hypertonicity of the muscles of mastication on the right side and a decrease of the basic tone of the chewing muscles on the left. This means that the muscle activity of the M. Masseter and M. Temporalis react to a change in the position of the foot produced by a synthetic shoe inlay (Valentino et al., 2002).

An electromyographic examination by Bergamini (2008) among 24 women and men aged 23-25 years produced the following results: an acrylic plate puts the occlusion of patients with malocclusion patterns (midline deviation, too narrow upper jaw or lower jaw, head forward position, …) in the most normal position possible. This has the consequence that a significant decrease in the basic tone of the M. Sternocleidomastoideus, the M. Erector spinae and the M.

Soleus can be observed and the difference in the muscle tone between the left and the right side is more equal in comparison with the measurements without the acrylic plate.

The interrelation of the mandible with the body posture was evaluated by Kiwamu et al. (2007). The results of this study are similar to those of the EMG study by Valentino et al. (2002). Also Kiwamu et al. (2007) found an interrelation between changes in the foot on one side and an increase in the muscle tone in the region of the jaw on the same side. In this study a heel lift on the right side is used and the occlusion forces are measured on the side with the heel lift in comparison with the other side. The authors of the study use a computer-aided occlusion-analysis-system for the collection of the data and the analysis. 45 test persons are involved in this study.

There are numerous recent studies in the field of orthodontics about possible influences of the teeth and jaws on other body structures. They mostly focus on the region of the spine and pelvis or look at leg length differences. Hanke et al. (2007) found a total of 359 articles about dental anomalies and orthopaedic peculiarities. 266 (74%) of those articles focused on the spine and the position of the head, 53 (14.7%) looked at pelvic asymmetries and 35 (9.7%) evaluated leg length differences.

Lippold et al. (2000) examine correlations of orthodontic findings and orthopaedic findings. In the cases of 50 patients between the ages of 4 and 55 years Lippold identifies statistically significant correlations between jaw asymmetries/cross-bite and pelvic asymmetries ($p=0.015$) or functional leg length differences ($p=0.009$). However, he does not find significant correlations in the cases of patients with Angel Class I, II, III occlusion.

The significant correlations in particular between jaw asymmetries/ cross-bite and leg length differences indicate that there could be interrelations between a cross-bite and changes in the leg.

In contrast to the aforementioned study another study by Dußler et al. (2002) among 29 children with and 28 children without a midline deviation of the mandible does not detect statistically significant correlations with asymmetries of the supporting or locomotor systems. What is noticeable is the great number of orthopaedic findings. 74% of all orthopaedically examined children had problems like scolioses, pelvic asymmetries, shoulder asymmetries, thorax asymmetries, pathological sagittal profiles of the spine and foot deformities. However, no significant difference could be observed between children with a midline deviation of the mandible (76% orthopaedic findings) and the control group without mandibular midline deviation (71% orthopaedic findings).

Already a slight leg length difference results in an asymmetric pressure pattern of the foot. This is the result of a study among 25 patients at the age of 15 with a leg length difference. The leg length difference was measured by means of radiology and was 2.8 cm (SD 1.7) on average. The stance phase of the shorter leg is shorter, the load (force) of the whole foot of the longer leg is greater (Pertunen et al., 2004).

By means of posturography Ohlendorf et al. (2009) examine whether a cross-bite has an influence on the body posture. Posturography (test of balance) is an assessment technique to determine the function of balance control when the lower extremities are loaded. 65 children and adolescents (28 male, 37 female) participated in the study; 32 test persons with a cross-bite and 33 without a cross-bite were posturographically assessed and the results compared. The Interactive Balance System (IBS) was used for the assessment. The IBS measures the vertical forces in the regions of the forefoot and hindfoot by means of four force plates. These vertical forces are measured in eight standardized test positions, which makes it possible to transform the force-time-signals into frequencies to analyse them. The results do not indicate a correlation between a cross-bite and the sensomotoric system.

The quoted studies show very different results. Many factors can have an influence on the occlusion. Various models can be used to demonstrate possible interrelations between the occlusion and the locomotor system. In the context of this study the most essential issue is to put together two groups that are as homogeneous as possible and differ only with regard to their occlusion pattern.

3. Methodology

This chapter will outline the basic structure of the present study. It contains a description of the study and control groups, the inclusion and exclusion criteria, how the study was carried out and what materials were used.

3.1 Study design

The aim of the study is to evaluate whether there is a correlation between a unilateral cross-bite and the loading of the foot during the stance phase. More precisely, the study looks at whether there is a difference between the loading of the left and the right foot of the test persons in the study and the control groups. In the case of an asymmetry in the loading of the feet in the study group (cross-bite group) a correlation analysis helps to find out whether this asymmetry correlates with the presence of the bite anomaly “unilateral cross-bite”.

The present study is a fundamental study with at least ten test persons with a normal occlusion in the control group and at least ten test persons with a unilateral cross-bite diagnosed according to orthodontic classification criteria (cf. Chapter 3.2) in the study group.

In order to determine the parameters that are to be examined a pilot study is implemented beforehand where various measurements are carried out among three children per group.

3.2 Inclusion and exclusion criteria regarding the patient sample

Inclusion criteria study group (cross-bite group):

This group comprises children aged 7 to 14 years with the orthodontic diagnosis “unilateral cross-bite”. The children must not have an occlusion classified as Angel Class II or III. The children were recruited in an orthodontic practice. The diagnosis is based on the analysis of x-ray images. The x-ray images were taken routinely because of the bite anomaly in order to plan further orthodontic treatments and for the purpose of documentation. Thus the children did not have to be exposed to additional x-ray radiation because of this study. When a child met the inclusion criteria the parents were invited to let their child participate in the study.

Inclusion criteria control group (normal bite group):

This group comprises children aged between 7 and 14 years with an orthodontic diagnosis of an Angel Class I occlusion. The children must not have a cross-bite or open bite. Due to ethical reasons the diagnosis can only be based on the inspection findings by a dentist. Ethically it cannot be justified to subject the children to an examination by means of x-rays only for the purpose of this study because routinely no x-ray examination would be necessary. To recruit children with an Angel Class I occlusion for this study approximately 200 children of the elementary schools in Rankweil (Austria) were given an information sheet for their parents on the occasion of the routine dental examination at their schools. The children also received the protocol of the examination findings where the dentist had documented the position of their teeth. In cases where the position of the teeth was diagnosed as "healthy" the parents were asked to voluntarily participate in the study with their children. In the routine dental examination at school the following classification was used: 1 = healthy, 2 = lower jaw, overbite, 3 = lower jaw, underbite, 4 = cross-bite, 5 = open bite, 7 = crowding. (cf. Form in the Annex).

Exclusion criteria:

Children who currently wear braces or orthodontic devices (longer than 6 weeks); children who had to wear braces or orthodontic devices in the past; fractures of the legs, feet, cranium, jaw; surgical interventions in the regions of the legs, feet, jaw; neuromuscular diseases (Xue Liu et al., 2005), polytraumas, acute soft tissue injuries, custom-fitted shoe inlays.
All these issues were clarified and discussed with the accompanying parent during the case history.

Patient sample:

24 children, 14 girls (58%) and 10 boys (42%) with an average age of 8.5 (+- 1.38) years were examined. 10 children belonged to the control group and 14 children belonged to the cross-bite group.
It soon became obvious that it was necessary to sub-divide the cross-bite group in one group with the cross-bite on the left side and another group with the cross-bite on the right side in order to identify side-related patterns (cf. Chapter 2.3). Ten children had a left-sided cross-bite and four children had a cross-bite on the right side. Due to the small number of test persons in the group with the unilateral cross-bite on the right side the results of this group were not interpreted for statistical reasons and the whole group was excluded from the study.

3.3 Implementation of the study

On the day of the examination the children and the accompanying parent were first asked to answer several questions in the case history: Firstly, the name, date of birth/age and information concerning fractures, operations, diseases, accidents, inlays in the child's shoes and dominant hand were recorded. Then, the child's height and weight were measured.

Subsequently, the supporting leg was identified by means of a quick test: the child is asked to stand upright in front of the practitioner with the feet closed (cf. Fig.8). This is the starting position. Next, the child is asked to put the feet apart. The task is to lift one leg. If the child lifts the left leg and puts to the side, the right leg is qualified as supporting leg because it was not lifted from the floor (cf. Fig 9). For reasons of reliability it is important that the practitioner does not show the child how to lift the leg because the child would then just mirror the movement. This statement is based on the experiences of the author in his work with children.

Fig.8: Starting position
Identification of supporting leg

Fig.9: Final position
Identification of supporting leg.

Subsequently an osteopathic examination of the locomotor system was carried out in order to document possible interrelations from an osteopathic point of view and to gain more experience.
After the osteopathic examination the evaluation by means of a force plate was explained to the child. The method that was chosen for the force plate measurement was an approach where the child was asked to make the third step onto the force plate. The sequence of steps was rehearsed during a few test measurements and the children coped well with it. A study evaluating the problem of step sequences in paedographic measurements among children showed no difference between the number of steps (one step or several steps) before the foot hits the force plate. However, the “midgait analysis” is quite representative for a normal gait pattern (Oladeji, 2008; Bryant et al., 1999).

Before the measurement the child was shown how to start to walk, e.g., with the left foot, then to put the right foot forward and to step onto the force plate with the left foot before continuing to walk several steps after the plate. Subsequently, a mark (adhesive tape) was placed onto the floor to mark the starting point from which the child should start walking. This starting position depended on the step length of the individual child and was determined through several trial walks. In addition, another mark was put on the floor approximately two metres behind the force plate, indicating the distance to which the child should continue to walk in order to avoid that the children slowed down their steps during the actual measurement. After all of this the child had a few minutes time to practice the procedure with the accompanying parent. In the meantime the data that was collected before was entered in the database of the computer. Then, the child was asked whether he/she was ready. If the child was ready, he/she walked over the force plate five times with the left foot and five times with the right foot. The children were bare-footed and free to choose the speed of walking.

3.4 Measuring methods

A specially developed examination form was used in this study. In this form the following information was recorded in writing: name, date of birth/age, fractures, operations, diseases, accidents, inlays, orthodontic regulations, dominant hand and the leg that was identified as supporting leg.

The body weight was measured with calibrated scales (Seca Waage Modell 701). In addition, the body height in upright stance was measured with a mechanic measuring stick (Seca 240).

The measurement of the loading during the stance phase was carried out by means of the ‘Emed® Pedographie System’ of the company Novell/Munich. With the ‘Emed® Pedographie System’ the plantar distribution of pressure can be exactly measured and analysed. The system comprises plates to measure the pressure and the related software – database to record and save the measured data. The Emed® - plates work with calibrated capacitive sensors.

It has a good reliability of repeated measurements ($r > 0.90$) (Gurney et al., 2008; Graf, 1993; Riad et al., 2007; Bryant, 1999; Bosch et al., 2009). The Emed® System has a good reproducibility and can be used in an orthopaedic clinic to measure pathological findings (Putti et al., 2007). This also applies to the Emed® System that is used at the Landeskrankenhaus (regional hospital) Rankweil (Maetzler et al., in Press).

The basis for the measurements in this study is formed by the following three parameters from the recorded data (Novel-Win, 1999):

1. Pressure: the pressure is measured locally by each sensor of the sensor matrix.
2. Location: the system records where the pressure occurs (to define the location a system-related coordinate plane is used).
3. Time: the moment at which the measured pressure occurred is recorded.

Figure 10 illustrates the measuring process at the gait laboratory of the Department for Physical Medicine and Rehabilitation of the Landeskrankenhauses Rankweil (Vorarlberg, Austria).

Figure 10. Measuring process

The Emed® force plate (emed-at/m) has a size of 610 x 323 x 18 mm; its sensor surface has a size of 240 x 380 mm. The plate has 1760 sensors and a resolution of 2 sensors / cm^2. The measurement frequency is 25/30.50.60 Hz. The pressure ranges from 10 to 950 kPa and has a pressure resolution of 10 kPa. The accuracy is +-7% ZAS. The hysteresis is smaller than 3%. The temperature range is 15-40 °C. The mechanical crosstalk is -40 db. The cable length is 5 m (Novel, 2008).

In order to identify abnormalities in the two groups the following parameters were calculated by means of ANOVA (one-factor variance analysis) on the basis of the five measurements per side (left and right foot) for each child:

- *Contact area (cm2*) = this corresponds to the surface of the foot that has contact to the floor when loaded.
- *Force time integral* (N*s) = the surface under the curve, which describes the force (N=Newton) on the y-axis and the time(s) on the x-axis. The integral describes the size of the resulting surface under this curve.

- *Instant of maximum force* (%ROP) = the moment when the greatest vertical force occurs. %ROP means that the time of foot roll-over, which normally is measured in seconds, is normalized in %, so that the different steps of the different test persons can be compared. This means that the phase from the first contact of the heel until toe-off corresponds to 100%.
- *Instant of peak pressure* (%ROP) = the moment when the highest pressure occurs.
- *Maximum force* (N) = the maximum force measured for each step.
- *Mean pressure* (kPa) = the average pressure per step.
- *Peak pressure* (kPa) = the maximum pressure per step.
- *Pressure time integral* (kPa per second) = the surface under the curve which describes the pressure (kPa) on the y-axis and the time(s) on the x-axis. The integral describes the size of the resulting surface under this curve.

The parameters were selected on the basis of a pilot study with 3 test persons per group. The parameters that were conspicuous were selected for calculation.

In order to identify possible patterns, e.g.: cross-bite left causes a different loading of the forefoot, the foot parameters were divided into eleven areas by means of the "E-Med Statistik 14.3.12" software and its function "Automask" (cf. Figure 11). These areas are (Novell, 2008):

- M11 = corresponds to Calcaneus lateral = heel
- M08 = corresponds to Calcaneus medial = heel
- M10 =. corresponds to midfoot-medial = metatarsus
- M09 = corresponds to midfoot-lateral = metatarsus
- M03 = corresponds to Os Metatarsale 1 = forefoot
- M04 = corresponds to Os Metatarsale 2 = forefoot
- M05 = corresponds to Os Metatarsale 3 = forefoot
- M06 = corresponds to Os Metatarsale 4 = forefoot
- M07 = corresponds to Os Metarsale 5 = forefoot
- M01 = corresponds to Ossa Digiti 2,3,4,5 = toes 2-5
- M02 = corresponds to Os Digitus 1 = halux

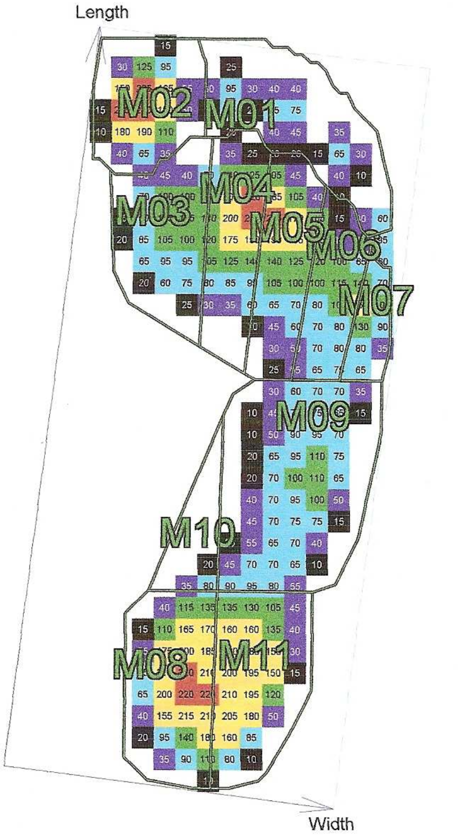


Figure 11. Foot areas according to Automask

3.5 Analysis

The clinical examination of the children was blinded, i.e. the examiner did not know what form of occlusion the children had. For the analysis the measured data was anonymized. The examination was carried out during the normal daily work at the Department for Physical medicine and Rehabilitation (Abteilung für Physikalische Medizin und Rehabilitation) at the regional hospital (Landeskrankenhaus) Rankweil under the direction of Prim. Dr. Bochdansky. This means the tests were carried out by a specialist who was blinded to the groups. Only the measured data were available. A pilot study with three test persons in each group helped to determine the parameters that were conspicuous concerning asymmetries of the left and right legs. The data of these parameters were used for the analysis. The data of the left and right legs were compared in each group. Significant differences were labelled as asymmetries and used for further statistical analyses.

For the statistical analysis of the correlation between cross-bite yes/no and the loading of the feet the raw data was exported from the Promed database as ASCII file and prepared in Excel 2003 for the analysis with the statistics program SPSS (15.0). The normal curve of distribution of the measured data was checked with the Kolmogorov-Smirnov test. The mean value for each side was calculated on the basis of the values measured for each of the five attempts. These mean values served as basis for the calculation of the point-biserial coefficient of correlation, Eta. The characteristics 'cross-bite' left and 'normal bite' were defined as independent variables.

4. Statistical analysis, results and interpretation

In the following analysis of the data the Novel Database Version 14.3.142 was used for the data output. The data was re-organized in Windows Excel Version 2003. The program SPSS Version 15.0 was used for the subsequent statistical analysis.

The analysis was confined to the parameters that stood out in the pilot study by suggesting asymmetries of the loading of the feet.

4.1. Asymmetries between the right and the left foot during the stance phase

The first step in the data analysis consisted in identifying asymmetries in the loading of both feet (left and right) within the two groups, i.e. the group with a unilateral cross-bite left (CBle) and the group with a normal bite (NB). The underlying hypotheses will be explained in detail in the following section:

Zero hypothesis:

In the stance phase no difference in the loading of the feet can be observed in the groups “unilateral cross-bite left” and “normal bite”.

Alternative hypothesis:

In the stance phase a difference in the loading of the left and the right foot can be observed in the “unilateral cross-bite left” group in comparison to the “normal bite group”.

To verify these hypotheses a one-factor variance analysis (ANOVA) is carried out. Since this kind of analysis presupposes a normal curve of distribution, this is checked by the Kolmogorov-Smirnov test. It showed that for the relevant measured values the assumption of normal distribution could be confirmed. Table 1 below presents the parameters for the whole foot.

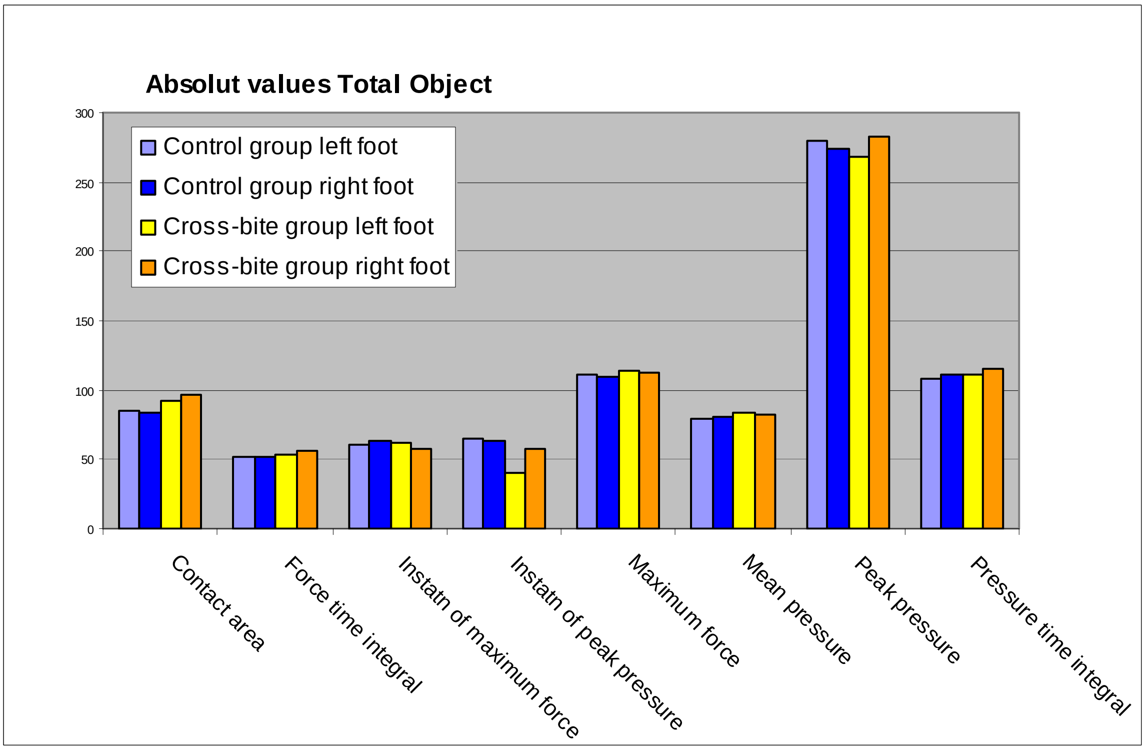
Table 1. Comparison of the mean values ANOVA and the standard deviation (SD) of the 'normal bite' group (NB) and the 'unilateral cross-bite left' group (CBle) for the whole foot.

	Normal bite group			**Left unilateral cross-bite group**		
Parametre	**left leg mean value + SD**	**right leg mean value + SD**	**p**	**left leg mean value + SD**	**right leg mean value + SD**	**p**
Contact area Total Object [cm2]	85.8+-9.6	84.1+-9.4	>0.1	92.16+-21.5	96.04+-21.1	>0.1
Force time integral Total Object [N*s]	52.5+-10.2	52.5+-7.9	>0.1	**53.4+-7.2**	**56.1+-7.4**	**0.048**
Instant of maximum force Total Object [%ROP]	60.7+-21.0	64.0+-19.5	>0.1	62.0+-22.5	57.7+-23.1	>0.1
Instant of peak pressure Total Object [%ROP]	64.9+-26.8	63.8+-27.9	>0.1	**40.9+-29.6**	**58.4+-30.3**	**<0.003**
Maximum force Total Object [N]	111.3+-5.9	109.8+-3.6	>0.1	113.8+-8.0	113.0+-7.6	>0.1
Mean pressure Total Object [kPa]	78.9+-10.9	80.7+-10.1	>0.1	84.2+-13.8	82.8+-12.9	>0.1
Peak Pressure Total Object [kPa]	279.9+-89.8	274.1+-123.7	>0.1	268.5+-64.8	282.7+-70.5	>0.1
Pressure time integral Total Object [kPa*s]	108.3+-32.7	111.7+-37.7	>0.1	110.5+-24.2	115.6+-20.8	>0.1

In the right half of Table one, presenting the data of the CBle group, the parameter 'Force time integral' (FTI) Total Object shows a significant asymmetry (p=0.048). A highly significant asymmetry (p=<0.003) can be observed in the parameter 'Instant of peak (IPP) pressure' Total Object. This indicates that the children of the CBle group reach the highest pressure per step considerably earlier on the left side than on the right side. In the NB group this is nearly symmetrical. The FTI value shows that the children of the CBle group load the right foot more strongly than the left foot. Concerning the absolute value (FTI) the NB group is exactly symmetrical. All other parameters do not show any significant differences.

Diagram 1 is a graphic illustration of the values in Table 1. The absolute values of the control group are light and dark blue, while the absolute values of the cross-bite group are displayed in yellow and orange. The numerical value on the x-axis can be assigned the parameter N, cm. The diagram shows clearly which parameters have the greatest asymmetry. These are the parameters ‘Instant of Peak Pressure’ and ‘Peak pressure’ of the absolute values for the total object.

Diagram 1. Absolute values of the right and left foot of the NB and CBle groups



To identify possible patterns in the asymmetry of the loading of the foot the individual regions of the left and right foot were compared within the two groups (Division of the foot into 11 areas by means of the Automask function, cf. Chapter in 3.4.). The identified asymmetries in the CBle group were subsequently compared with the NB group.

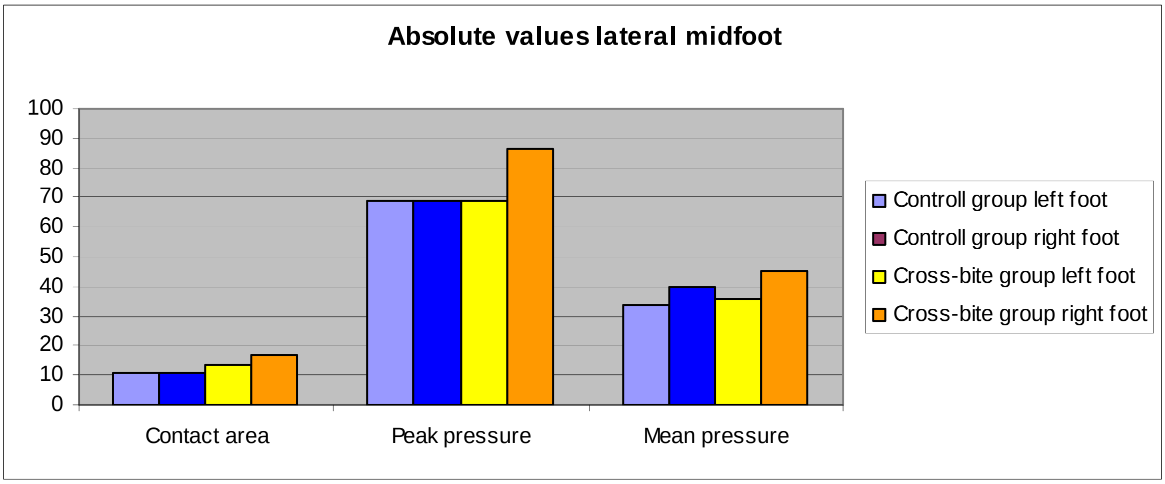
Table 2 presents the significant results ($p < 0.05$) of the comparison of the asymmetries in the ‘cross-bite left’ group with the asymmetries in the NB group. The 11 areas of the foot were compared to recognize possible correlations. A significant asymmetry of the loading of the foot can be observed in several parameters of the CBle group, in particular in the lateral midfoot region of the right foot (cf. Table and Diagram 2).

The contact area in the lateral midfoot region is very symmetrical in the NB group (10.8+-1.4 cm² left foot and 10.8+-1.5 cm² right foot). The contact area of the lateral midfoot region in the CBle group is 3.09 cm² bigger on the right side. Also the Peak pressure in the midfoot region is clearly greater (17.1 kPa/cm²) on the right side. In addition, also the mean pressure on the lateral midfoot region is greater (19.5 kPa/cm²) on the right side in the CBle group. However, a clear asymmetry can be observed also in the NB group as regards the Peak pressure and Mean pressure on the lateral midfoot.

Table 2 Comparison control group – cross-bite group (mean value, standard deviation SD and significance p)

	Normal bite group			**Left unilateral cross-bite group**		
Parameter	**Left leg mean value +SD**	**Right leg mean value +SD**	**p**	**Left leg mean value +SD**	**Right leg mean value +SD**	**p**
Contact area lateral midfoot in [cm²]	10.8+-+-1.4	10.8+-1.5	P=>0.1	13.51+-7.02	16.60+-5.3	P=0.0123
Peak pressure lateral midfoot in [kPa]	68.8+-21.2	80.9+-33	p=0.0315	69.1+-28.7	86.2+-33.0	P=0.0097
Mean pressure lateral midfoot in [kPa]	33.8+-11.5	40.1+-14.4	P=0.0176	35.5+-14.3	45+-17.6	P=0.0031

Diagram 2. Absolute values lateral midfoot region of the right and left foot in the NB group and CBle group



A comparison of the results of the data analysis with the hypotheses shows that the zero hypothesis could be refuted.

The alternative hypothesis, however, can be accepted considering the significant differences in the parameters ‘Instant of Peak Pressure Total Object’ and ‘Force Time Integral Total Object’.

4.2 Correlation between loading of feet and bite anomalies

The second data analysis focused on analysing the interrelation between the identified asymmetry of the loading of the feet and the presence of a unilateral cross-bite in order to identify a possible correlation. The following hypotheses are formulated:

Zero hypothesis:

No statistical correlation can be identified between the bite anomaly ‘unilateral cross-bite left’ and a unilateral loading of the foot during the stance phase.

Alternative hypothesis:

During the stance phase a correlation between the bite anomaly ‘unilateral cross-bite left’ and the unilateral loading of the foot can be observed.

To establish a statistical verification of a correlation between the significant parameters of the analysis regarding the symmetry of the loading of the feet and the bite anomaly a point-biserial correlation is calculated. The independent and dichotomous variable is the cross-bite left with the possibilities yes/no (1/0); all test persons of the NB group have the characteristic “no (0)”. The dependent variables are the parameters that were identified as significant in the analysis of the asymmetry of the loading of the feet (cf. Table 1 and 2 in Chapter 4.1).

Table 3. The mean values and standard deviation (SD) of the interesting parameters (FTI=Force time integral, IPP=Instant of peak pressure, CA=Contact area, MP=Mean pressure.)

Group	FTI total object left	FTI total object right	IPP total object left	IPP total object right	CA lat midfoot left	CA lat. midfoot right	MP lat. midfoot left	MP lat. midfoot right
Cross-bite left Mean value	178.5940	183.5540	45.3060	57.8440	13.3800	16.5000	36.1520	43.7940
Number of test persons	10	10	10	10	10	10	10	10
Standard deviation	62.39722	58.40458	25.19814	26.37295	7.07104	5.51624	12.53723	16.87920
Normal bite Mean value	152.3340	153.1300	64.8840	64.1040	13.3900	14.3300	33.8460	39.9680
Number of test persons	10	10	10	10	10	10	10	10
Standard deviation	48.43268	43.05031	16.77004	11.76054	3.83361	2.69405	8.53943	8.99098
Total Mean value	165.4640	168.3420	55.0950	60.9740	13.3850	15.4150	34.9990	41.8810
Number of test persons	20	20	20	20	20	20	20	20
Mean value	56.00760	52.31882	23.12679	20.13184	5.53584	4.36930	10.50695	13.30789

The values in Table 3 are the mean values of the significant parameters (cf. Chapter 4.1) of the normal distribution of the evaluated parameters, which have been checked with the Kolmogorov-Smirnov test. The mean values were calculated for each side on the basis of the individual values of the five steps on each side. These results serve as basis for the calculation of the point-biserial correlation coefficient, Eta.

Table 4. ANOVA Table (Significance of the Eta-coefficient)

Parameter	p
Force time integral total object left*group	.307
Force time integral total object right*group	.201
Instatn of peak pressure total object left * group	.056
Instant of peak pressure total object right * group	.502
Contact area lat midfoot left * group	.997
Contact area lat midfoot right * group	.278
Mean preasure lat midfoot left * group	.637
Mean prasure lat midfoot right * group	.535

A comparison of the Eta-coefficients (cf. Table 4) shows no significance regarding the evaluated parameters. However, a tendency can be observed regarding the parameter IPP left (p=0.056).

Table 5. Measures of Association (Level of correlation between bite and parameter)

Parameter	Eta	Eta Squared
Force time integral total object left * group	.241	.058
Force time integral total object right * group	.298	.089
Instant of peak pressure total object left * group	.434	.189
Instant of peak pressure total object right * group	.160	.025
Contact area lateral midfoot left * group	.001	.000
Contact are lateral midfoot right * group	.255	.065
Mean preasure lateral midfoot left * group	.113	.013
Mean preasure lateral midfoot right * group	.147	.022

Table 5 shows that there is no significant correlation between the individual parameters and the characteristic bite left yes/no. This means the zero hypothesis can be upheld.

5. Discussion

Considering the hypothesis “In the case of the diagnosed bite anomaly “unilateral cross-bite” correlations with alterations of the loading of the foot in the stance phase can be observed” and taking into account the results of the study, one can say: considerably more asymmetries of the loading of the left and right foot can be observed in the CBle group in comparison with the NB group. However, these asymmetries do not correlate with the cross-bite.

The following section will discuss the results of the evaluation of the symmetry in the loading of the feet. The second section will focus on the correlation of the results with the occlusion and the final section will consider some general issues.

If the measured parameters of the whole foot of the CBle group are compared with those of the NB group the following can be observed: The IPP value of the left foot has the tendency to be smaller in the CBle group. This means that the cross-bite group seemingly has a faster foot roll-over on the left side and the instant of peak pressure happens earlier. This is mainly due to the faster foot roll-over on the left side, but it cannot be attributed to one of the eleven areas (cf. Figure 11) on the foot in a more detailed analysis.
If one considers the measurement results regarding the contact area in the NB group the tendency of a symmetrical loading of the feet can be observed, while the results of the cross-bite group indicate the tendency of a larger contact area on the right side. It is interesting that the standard deviation in the cross-bite group is more than double the value of the control group, which can be an indicator for an inhomogeneous group.

The mean value of the Force time integral Total Object (N*s) is exactly symmetrical in the NB group. In the CBle group, however, a significant difference can be observed with a p-value of p=0.048 and a difference of 2.7 N*s between the left and right foot. The right foot is loaded more than the left one. It would be interesting to compare these results with those of a group with a ‘unilateral cross-bite right’ to find out whether this loading pattern is correlated with the side of the cross-bite. In a mixed group with test persons who have either a cross-bite on the left or on the right side this result will probably be distorted. In such a mixed group the mean value of the results would even out the differences. Therefore it is necessary to make sure that only children with a unilateral cross-bite on one side (either left or right) are in the same group in order to be able to confirm a side-related asymmetry. Since the number of test persons with a cross-bite on the right side (group cross-bite right, KBre) was too small in this study, no comparison can be made.

A comparison of the ANOVA values in the NB group with values calculated by Xue et al. (2005), who examined a group of 66 children aged between 6 and 16 years, showed that the results are very much consistent. Xue also used the Emed® system to obtain normal measurements of the loading of the children's feet in the stance phase. He evaluated the contact area, contact time, peak pressure, maximum mean pressure, pressure time integral, force time integral, instant of peak pressure, maximum force and instant of maximum force of nine regions of normal children's feet. Also mean values and standard deviations were calculated (Xue et al., 2008).

The results of the analysis regarding the lateral midfoot on the right side of the children in the CBle group indicate that particular attention to this region needs to be paid in future examinations.

A greater loading of the lateral midfoot as observed in the CBle group could have something to do with an asymmetrical muscle activity of the M. Soleus. A study by Bergamini et al. (2007) indicates a possible interrelation: The symmetry of the M. Soleus activity changes with the symmetry of the occlusion. If the occlusion is symmetrical, also the activity of the M. Soleus is symmetrical. Since the M. Soleus belongs to the M. Triceps surae and since this muscle is regarded as the strongest supinator of the subtalar joint (Platzer, 1991), a possible consideration would be that the increased activity of the M. Soleus causes a stronger supination of the subtalar joint during gait and thus leads to a greater loading of the lateral midfoot in the third phase of the stance phase. Bergamini carried out his examination among standing test persons. It would be necessary to evaluate the symmetry of the M. Soleus activity during gait and to analyse correlations with bite asymmetries.

The study of Korbmacher (2007) looked at 240 children among whom 55 children had a unilateral cross-bite. This study did not show any correlations between orthopaedic findings and the unilateral cross-bite, but it indicated that children with a cross-bite statistically had a greater incidence of a leg length difference ($p=0.002$), a pelvis asymmetry ($p=0.007$) or shoulder asymmetry ($p=0.004$). Despite the results of the study of Korbmacher (2007) the present study did not find any significant correlations between a unilateral cross-bite on the left side and the loading of the leg in the stance phase. This could be attributed to the fact that many factors that could influence the study results were not considered. Possibly also the small sample size plays a role in this context.

The interrelations that are responsible for the asymmetrical results of the cross-bite group need to be identified. One possibility would be a posturographic examination. In this regard, however, a study has been published recently which provides no evidence that a cross-bite has any influence on the sub-systems of the sensomotoric system (Ohlendorf et al., 2009).

Due to the small number of test persons the group with a unilateral cross-bite on the right side cannot be included in the interpretation of the study results. With four children only the group is too small to provide statistically valid evidence regarding the loading of the feet. However, it would be interesting to find out whether the loading pattern that was observed in the CBle group can also be observed (laterally reversed) among children with a cross-bite on the right side.

What is interesting is the incidence of a unilateral cross-bite on the left (71%) in comparison with a unilateral cross-bite on the right side (29%) among the children who participated in the study. This could possibly be linked with the birth process. During the delivery strong forces act upon the bone structures that in part are still cartilaginous. According to Möckel (2006) the most common presentation of the head is the vertex presentation left in more than 70% of the cases. This has an effect on the cranial base, which again has a strong influence on the development of the whole cranium and thus also on the jaw and its position.
This is confirmed by the study results of Cattaneo et al. (2005), who evaluated the circumstances of the birth process and its influence on the position of the teeth and observed certain correlations. Thus, from an osteopathic point of view, the form of occlusion can be linked with the presentation of the head during the birth process.

The children were very cooperative during the examination process. They tried very hard to do everything correctly. Still, the children were evaluated in a test situation. This is a factor, which, of course, plays a role in the examination. Nevertheless, the test situation was the same for both the children of the control group and the children of the cross-bite group, therefore this factor was regarded as something that one had to put up with in this study. An examination where the child walks over a force plate without knowing it would be preferable. However, such a measuring system was not available.

Children who had their seventh birthday only recently had more difficulties to execute the five measurement attempts in a concentrated way. Nevertheless, if the inclusion criterion age had been raised to eight years of age, a third of the children in the study would not have qualified as participants. Also, one can say that the older the children, the higher the probability that an orthodontic treatment has already been started by the dentist. And an orthodontic treatment would be an exclusion criterion. The oldest child in the study was 12 years old, because other older children were already undergoing orthodontic treatment. Thus one can say that the ideal age for such a study ranges between 8 and 12 years.

In this study no influence of the side of the supporting leg on the symmetry of the loading of the feet could be observed. In the control group the supporting leg was the left leg in the case of seven children and the right leg in the case of three children. In the cross-bite group six children had their supporting leg on the left side and four on the right side. The point-biserial correlation analysis regarding the characteristic ‘supporting leg’ left/right of both groups did not produce a significant result for the correlation coefficient Eta.

The observations of the examiner were also interesting. The examiner did not know whether the children had a cross-bite or normal occlusion but on the basis of the loading of the legs and the position of the pelvis he was able to determine the side of the cross-bite in 10 of fourteen cases. Often an eversion of the hindfoot (calcaneus) and a posterior ilium on the same side of the cross-bite could be observed. On the contralateral side an inversion of the calcaneus could be detected in many cases.

Regarding the question whether children who really did not have a cross-bite were recruited for the control group, the diagnosis by inspection by the dentist must be challenged. Is a diagnosis by inspection enough or are there any measuring instruments which could be used to verify a correct bite? A consideration of this question will be very important for future studies regarding the validity of the attribution of the test persons to the groups “normal bite” and “cross-bite”.

A partly highly significant ANOVA result of the parameters Instant of Peak pressure Total Object, Force time integral Total Object, Peak pressure lateral midfoot and Mean pressure lateral midfoot despite a small group size of only ten test persons is quite remarkable. However, these results must not hide the fact that a considerably higher number of test persons would be necessary to make a valuable statement regarding the symmetry of the loading of the feet. This study, however, could not find out what the significant differences can be attributed to.

It would be of advantage to carry out further studies to find out in how far the effects of a unilateral cross-bite are compensated. Possible additional examinations could be e.g. the loading of the feet in the standing position, a posturographic examination, where the cross-bite can be neutralized with the aid of cotton wool rolls in a second measurement or where a bite asymmetry is produced artificially in a group with test persons who have a normal occlusion.

From the perspective of the author and the orthodontist who was involved in the study it would be desirable to examine a larger number of children also with other forms of bite anomalies with regard to their loading of the feet. This could contribute to a better understanding of supposed interrelations and interrelations that are described in the literature (cf. Chapter 2.3)?! This could help a better understanding of possible connections between the occlusion and the feet in general.

6. Summary

Numerous studies examine possible interrelations between occlusion and its influences on the position of the shoulders, spine and pelvis and on the length of the legs (Fink 2003; Lippold 2000; Hanke et al., 2007; Dußler et al., 2002).

With the aid of electromyography Valentino et al. (2002) evaluate the effect of a temporary synthetic shoe inlay on the chewing muscles. If the arches of the right foot are brought into a valgus position, a hypertonicity of the chewing muscles on the left side can be observed. By means of electromyography Berganini (2008) examines how a faulty occlusion, which is put into the best possible correct position with the aid of an acrylic plate, has an influence on various muscles. His observation is that an improved occlusion has the effect of reducing the basic tone of the M. Sternocleidomastoideus, the M. Erector spinae and the M. Soleus. Also the difference in the muscles tone between the left and right side becomes more balanced.

These study results (cf. Also Chapter 2.3) are the background of the present study. The following question arises: Can interrelations between a unilateral cross-bite and the loading of the feet be demonstrated in the stance phase of the gait cycle?

To evaluate a possible interrelation of a unilateral cross-bite with the loading of the foot during the stance phase 20 children were examined by means of pedography (Emed® - Novel). Among the test persons were 10 girls (50%) and 10 boys (50%) with an average age of 8.5 (+-1.38) years. In the examination the loading of the foot during the stance phase was measured.

The control group comprised ten children with a correct bite (Angel Class I, no cross-bite, no open bite). The cross-bite group comprised ten children with the orthodontic diagnosis "unilateral cross-bite left". The clinical observations and the results of the pilot study indicate an asymmetrical loading of the feet in the cross-bite group in comparison with the control group. Therefore the first analysis of the study data focused on the symmetry between the left and right leg. In the second phase the identified asymmetries of the loading of the feet are examined with regard to a correlation with the cross-bite on the left side.

The examinations were carried out by means of the Pedography Emed® ST2 (Novell München) system at the regional hospital (Landeskrankenhaus) Rankweil/Vorarlberg (Austria). The measured data were grouped in the Novel database and tested with a one-factor ANOVA analysis. The measured parameters that showed a significant right/left difference were exported as ASCII file into EXCEL and reorganized in an EXCEL database for the SPSS presentation. The normal distribution of the measured parameters was verified with the Kolmogorov-Smirnov test. In addition, the mean values of the five individual values for each side were calculated. They served as basis for the calculation of the point-biserial correlation coefficient Eta. The characteristics cross-bite left and normal bite were defined as independent variables in this context.

The result of the ANOVA calculation shows that the cross-bite left group reaches the highest pressure (Instant of Peak Pressure) significantly earlier ($p = <0.05$) on the left side. This means that the foot roll-over on the left side is faster. Another observation is that the cross-bite group also loads the right foot more. The Instant of Peak Pressure on the left side is 40.9

SD +-29.6 % ROP and on the right side 58.4 SD +-30.3 % ROP. The Force Time Integral of the left foot is 53.4 SD +-7.2 N*s and 56.1SD +-7.4 N*s of the right foot. The normal bite group shows a symmetrical loading of the feet.
An evaluation of the individual regions of the foot by means of a mask that subdivides the foot in 11 areas highlights a considerably bigger contact area and a higher loading on the right side in the region of the lateral midfoot in the cross-bite group.

If the significant results of the symmetry analysis of the loading of the feet are brought into correlation with the occlusion, the statistical analysis does not indicate a significant correlation. However, a tendency con be observed regarding the Instant of Peak Pressure on the left side (p=0.056).

7. Bibliography

Angle E.H.: Treatment of malocclusion of teeth. White Dental Manufacturing Co., Philadelphia, 1907.

Bergamini M., Pierleöni F.: Dental occlusion and body posture. Cranio vol 26(1), 25-32, 2008

Bernar L., Van Assche R.: Gelenke der unteren Extremität Mobilisation und Korrektur. Verlag für Osteopathie, Dr. Erich Wühr, Kötzing Bayer Wald, 1993.

Bevilaqua-Grossi D., Chaves T.C., Lovato M., De Oliveira A.S., Regalo S.C.: Assessment of head tilt in young children with unilateral posterior cross bite by video recording. J. Pediatr. Dent., Winter 32(2), 159-164, 2008.

Bosch K., Rosenbaum D.: Medizinisch-Orthopädisch- Technik 3 13-18 2006

Bosch K., Gerss J., Rosenbaum D.: Preliminary normative values for foot loading parameters of the developing child. Gait & Posture 26, 238-247, 2007.

Bosch K., NagelA., Weigend L., Rosenbaum D.: From „first“ to „last“ Step in life – Pressure patterns of three generations. Clinical Biomechanics Okt.24/8, 676-681, 2009.

Bryant A., Singer K., Tinley P.: Comparison of reliability of plantar pressure measurements using the two-step and midgait methods of data collection. Foot Ankle Int. Oct. 20(10), 646-650, 1999.

Cattaneo R., Monaco A., Streni O., Serafino V., Giannoni M.: Birth delivery trauma and maloccluion. Journal Clin. Pediatr. Dent. Spring 29(3), 185-188, 2005.

Cavanagh P.R., Morag E., Boulton A.J.M., Young M.J., Deffner K.T. and Pammert S.E.: The Relationship of static foot structure to dynamic foot function. Journal Biomechanics Vol. 30 No. 3, pp. 243-250, 1997.

Cavanagh P.R., Michioshi A.C.: Techniques for the display of pressure distributions beneath the foot. J. Biomech. 13, 69-75, 1980.

Clausnitzer R.: Kieferorthopädische Grundlagen für Logopäden und Sprachtherapeuten. Verlag modernes lernen, Dortmund, 2002.

Colloca A.: How osteopathie can help explaining the aetiologie and assist dentist in cause of lateral cross-bite malocclusion. B. Sc. Osteopathy, European School of Osteopathy, Maidstone Academie, Year 2004-2005.

Dußler E., Raab P., Kunz S., Witt E.: Mandibuläre Mittellinienverschiebung und Asymmetrien des Halte- und Bewegungsapparates bei Kindern und Jugendlichen. Manuelle Medizin 40, 116-119, Spinger Verlag, 2002.

Eversaul G.: Dental Kinesiology. P.O:BOX 19476, Las Vegas, Nev. 891179, 1977.

Fink M., Tschernitschek H., Stiesch-Scholz M., Wähling K.: Kraniomandibuläres System und Wirbelsäule. Manuelle Medizin 41, 476-480, 2003.

Fink M.: Personal communication. Klinik f. Physikalische Medizin und Rehabilitation, Medizinische Hochschule Hannover, 30625 Hannover, 31.12.2007.

Götz-Neumann K.: Gehen verstehen. 2.unveränderte Auflage, Thieme Stuttgart, 2003.

Graf P.M.: The EMED System of foot pressure analysis. Clin. Podiatr. Med. Surg. Jul.10(3), 445-454, 1993.

Gurney J.K., Kersting U.G., Rosenbaum D.: Between day reliability of repeated plantar pressure distribution measurements in a normal population. Gait Posture May 27(4), 706-709, 2008.

Harzer W.: Lehrbuch der Kieferorthopädie. Hanser Verlag, München, Wien, 1998.

Honikel M., Bruderhofer A.: Das Craniomandibuläre System und seine Effekte auf die Körperhaltung. Teil 1-3. 8.Jahrg., Heft 2/2007, S 22-26, Elsevier GmbH. 8.Jahrg., Heft 3/2007, S 16-21, Elsevier GmbH 8.Jahrg., Heft 4/2007, S 4-9, Elsevier GmbH 2007.

Hanke B. A., Motschall E., Türp J.C.: Bein, Becken, Kopf, Wirbelsäule und zahnmedizinische Befunde – welches Evidenzniveau liegt vor? Journal of Orofacial Orthopedics 68, 91-107, 2007.

Kantorowicz A.: Handwörterbuch der gesamten Zahnheilkunde. Verlag von Hermann Meusser Berlin und Johann Ambrosius Barth, Leipzig, 1929.

Kiwamu S., Noshir R.M., Emad F.A., Albert G.F., Hiroshi H., Takao K., Atsuro Y.: Examination of Relationship Between Mandibular Position and Body Posture. Cranio 25, 4 Okt. 237-249, 2007.

Korbmacher H., Koch L., Eggers-Stroeder G., Kahl-Nieke B.: Associations between orthopaedic disturbances and unilateral cross bite in children with asymmetry of upper cervical spine. European Journal of Orthodontics, (29) 100-104, 2007.

Korkhaus G.: Moderne orthodontische Therapie. Verlag von Hermann Meusser, Berlin, 1928.

Liem T.: Praxis der kraniosakralen Osteopathie. 2.Auflage, Hippokrates Verlag, Stuttgart, 2003.

Lippold C., Ehmer U., Van den Bos L.: Beziehung zwischen kieferorthopädischen und orthopädischen Befunden. Manuelle Medizin, 38:346-350, Springer Verlag, 2000.

Maetzler M., Bochdansky T., Abboud R.J.: Normal pressure values and repeatability of the Emed® ST2 system. In Press, 2009.

Michelotti A., Farella M., Buonocore G., Pellegrino G., Piergentili C., Martina R.: Is unilateral posterior crossbite associated with leg length inequality?, European Journal of Orthodontics 29, 622-626, 2007.

Möckel E., Noori M.: Handbuch der pädiatrischer Osteopathie. 1.Auflage, Elsevier Verlag, München, 2006.

Neuhuber W.: Anatomie und funktionelle Neuroanatomie der oberen Halswirbelsäule. Manuelle Medizin 45, 227-231, 2007.

Nielsen K.D., Hvid I., Moller-Madsen B.: Plantar pressure distribution pattern of children in different ages. Clin. Biomech 18, 29-30, 2003

Nigg B.: Biomechanics of the musculo-skeletal system. 2nd edition, Wiley&Sons, Chichester and New York, 2007.

Novel Hompage: http://www.novel.de/ger/productinfo/systems-emed.htm, 2008.

Novel GmbH.: Handbuch novel-win, München, November, 1999.

Oladeji O., Stackhouse C., Gracely E., Orlin M.: Comparison of the two-step an midgait methods of plantar pressure measurement in children. Journal of the American Podiatric Medical Association, July/August, Vol.98 No.4, 268-277, 2008.

Ohlendorf D., Büntemeyer B., Filmann N., Schwesig R., Kopp S.: Posturographische Untersuchungen bei Kindern und jungen Erwachsenen mit und ohne Kreuzbiss. Manuelle Medizin 47, 33–38, 2009.

Perry J.: Ganganalyse. Urban und Fischer Verlag, München Jena, 2003.

Perttunen J.R., Anttila E., Södergard J., Merikanto J., Komi P.V.: Gait asymmetry in patients with limb length discrepancy. Scand J. Med. Sci. Sports 14, 49-56, 2004.

Plazer W.: Taschenatlas der Anatomie. Band 1, Bewegungsapparat, Thieme Stuttgart, 1991.

Putti A.B., Arnold G.P., Abboud R.J.: Foot pressure differences in men and women. European Foot and Ankle Society, Available online, 13.May, Published by Elsevier Ltd., 2009.

Putti A.B., Arnold G.P., Cochrane L.A., Abboud R.J.: Normal pressure values and repeatability of the Emed ST4 system. Gait Posture Apr. 27(3), 501-505, 2007.

Rakosi T., Jonas I.: Kieferorthopädische Diagnostik. Georg Thieme Verlag, Stuttgart, New York, 1989.

Riad J., Cleman S., Henley J., Miller F.: Reliability of pediobarographs for paediatric fot deformity. Journal Child. Orthop. Nov. 1(5), 307-312, 2007.

Schupp W.: Kraniomandibuläre Dysfunktion und deren peripheren Folgen. Manuelle Medizin 43, 29-33, 2005.

Schupp W.: Manuelle Medizin und Kieferorthopädie. Ein Modell für eine integrative Vernetzung. Manuelle Medizin 41, 302-308, 2003.

Shik Yin C., Jun Lee Y., Jin Lee Y.: Neurological influences of the temporomandibular joint. Journal of Bodywork and Movement Therapists 11, 285-294, 2007.

Sutherland D., Olshen R., Cooper L., Woo S.: The development of mature gait. Journal Bone Joint Surg. Am. Apr. 62(3), 336-353, 1980.

Univeritätsklinik Münster: Entwicklung des Kinderfußes (laufende Studie über 15 Jahre) http://kidfoot.klinikum.uni-muenster.de/3666.html, 2008.

Valentino B., Melto F., Aldi B., Valentino T.. Correlation between interdental occlusal plane and plantar arches. An EMG Studie. Bull. Group. Ins. Sci. Stomadol. Odontol. 44, 10-13, 2002.

Virgillo F., Ferrario M., Chiarella Sfoorza D., Johannes H., Schmitz D., Taroni A.: Occlusion and center of foot pressare variation. Is there a relationship? The Journal of Prosthetic Dentistry Vol. 76 iss 3, 302-308, 1996.

Volpon J.B.: Footprint analysis during the growth period. J. Pediatr. Orthop. 14(1), 83-85, 1994.

Wernham J.: Mechanics of the spine. Yearbook of Institute of Applied Osteopathy, Maidstone, 1956.

Wernham J.: Mechaniks of the spine. Yearbook of Maidstone College of Osteopathy, Maidstone, 1985.

Wühr E.: Kraniofaziale Orthopädie. Verlag für Ganzheitliche Medizin, Bad Kötzing/Bayer. Wald, 2008.

Xue C. L., Thometz J.G., Tassone C., Barker B., Lyon R.: Dynamic plantar pressure measurement fort he normal subjekt – free-mapping model for the analysis of paediatric foot deformities. Journal of paediatric Orthopaedics Jan-Feb. 25(1), 103-106, 2005.

Xue C. L.: Personal communication. Musculoskeletal Functional Assessment Center, Dept. of Orthopaedic Surgery, Children's Hospital of Wisconsin, E-mail, 2009.

8. Annex

8.1 List of figures

8.2 Examination form – Declaration of consent – Dental examination form

Examination form:

Date:

Name: **Tetrax**

Code:

Age:

Weight:

Height:

Diagnosis:

Dentist:

Fractures:

Operations:

Diseases:

Accidents:

Shoe inlays:

Braces or other orthodontic devices:

Dominant hand:

Supporting leg:

C0/C1:

Rot left

Rot right

Lat left

Lat right

Flexion

Extension

Forward flexion test:

Declaration of consent

I ________________________________ declare my consent that the data collected during the examination of my child

____

are used for scientific purposes.

Rankweil, . . 2008

für Eltern

[redacted]	[redacted]	[redacted]	[redacted]
Name des Kindes	Vorname	Vers.-Nr.	Geb.-Datum
[redacted]	[redacted]	[redacted]	[redacted]
Name des Versicherten	Vorname	Vers.-Nr.	Geb.-Datum
[redacted]	6830	Rankweil	
Straße	PLZ	Ort	
VS- Markt	Rankweil	2b	
Kindergarten / Schule	Ort	Gruppe / Klasse	

Putzt Ihr Kind die Zähne?
☒ morgens ☐ mittags ☒ abends ☐ zwischendurch

Verwendet es nach dem Essen Kaugummi?
☐ morgens ☐ mittags ☐ abends ☒ zwischendurch

Geht es zum Zahnarzt?
☒ 2x jährlich ☐ 1x jährlich ☐ seltener ☐ bisher nie

Hat es eine Zahnspange?
☐ ja ☐ nein ☐ Zahnspangenbehandlung abgeschlossen

Verwenden Sie fluoridiertes Kochsalz?
☒ regelmäßig ☐ selten ☐ nie

Ich bin mit der kostenlosen Untersuchung meines Kindes, der Verarbeitung der Untersuchungsdaten durch die Sozialversicherungsträger und die aks Zahnprophylaxe GmbH, sowie der Weitergabe der anonymisierten Daten für wissenschaftliche Zwecke einverstanden. Dieses Einverständnis kann ich jederzeit widerrufen.

8.5.08 [redacted]

Datum — Unterschrift eines Erziehungsberechtigten

Bei der Untersuchung auszufüllen

Karies:

- 0 = gesund
- 4 = Karies
- 5 = Füllung
- 51 = Fissuren-versiegelung
- 6 = extrahiert
- 7 = Füllung und Karies
- 8 = beschädigt Unfall
- 9 = fehlend Zahnwechsel oder nicht sichtbar wegen zementierter Zahnspange

	0 (55)	4 (54)	4 (53)	(52)	(51)	(61)	(62)	4 (63)	4 (64)	4 (65)	
0 (16)	(15)	(14)	(13)	0 (12)	0 (11)	0 (21)	0 (22)	(23)	(24)	(25)	0 (26)
0 (46)	0 (45)	(44)	(43)	0 (42)	0 (41)	0 (31)	0 (32)	(33)	(34)	(35)	0 (36)
	(85)	4 (84)	0 (83)	(82)	(81)	(71)	(72)	0 (73)	4 (74)	4 (75)	

graue Kästchen = bleibende Zähne

Zahnstellung:

- ☒ = gesund
- 2 = UK Rückbiss
- 3 = UK Vorbiss
- 4 = Kreuzbiss
- 5 = offener Biss
- 7 = Platzmangel

Empfohlen:

☒ Zahnarztbesuch ☒ Karieskontrolle beim Zahnarzt ☐ Zahnstellungskontrolle beim Zahnarzt
☒ Fissurenversiegelung durch den Zahnarzt ☐ Professionelle Zahnreinigung beim Zahnarzt

15.5.08.

Datum — Stempel, Unterschrift des Zahnarztes

8.3 Measurement results Control group

6 - biss 2 li		Left	Right		
15 - biss 2 re		foot	foot		
Parameter	Mask	Value 1	Value 2	P	Diff.
Anterior plantar angle		30,9 ± 2,1	29,7 ± 2,0	0,046	1,2
Ar+Al		12,71 ± 2,90	10,62 ± 3,96	0,063	2,09
Arch index		0,23 ± 0,03	0,22 ± 0,04	0,383	0,01
Area between the axis and gait line (Ar)		8,40 ± 3,42	4,04 ± 3,38	0,000	4,36
Area between the gait line and axis (Al)		4,31 ± 3,13	6,57 ± 3,46	0,027	-2,26
Average mean pressure	big toe	43,5 ± 12,8	36,4 ± 11,3	0,119	7,1
Average mean pressure	Lateral hindfoot	59,0 ± 8,3	63,0 ± 7,4	0,177	-4
Average mean pressure	Lateral midfoot	26,5 ± 6,8	25,9 ± 4,3	0,797	0,5
Average mean pressure	Medial hindfoot	67,8 ± 8,8	73,8 ± 10,5	0,104	-5,9
Average mean pressure	Medial midfoot	23,6 ± 8,2	20,9 ± 9,4	0,415	2,7
Average mean pressure	MH1	39,0 ± 8,6	35,6 ± 8,0	0,279	3,3
Average mean pressure	MH2	60,0 ± 15,6	61,2 ± 12,7	0,805	-1,3
Average mean pressure	MH3	60,9 ± 17,0	62,0 ± 14,3	0,847	-1,1
Average mean pressure	MH4	50,7 ± 10,4	52,8 ± 8,5	0,548	-2,1
Average mean pressure	MH5	42,2 ± 9,3	44,2 ± 8,5	0,545	-2
Average mean pressure	Toes 2345	25,1 ± 5,4	24,2 ± 6,1	0,668	0,9
Average mean pressure	Total object	54,1 ± 4,9	54,6 ± 4,8	0,785	-0,5
Begin of contact	big toe	32,3 ± 18,0	34,4 ± 14,5	0,734	-2
Begin of contact	Lateral hindfoot	0,0 ± 0,0	0,1 ± 0,4	0,326	-0,1
Begin of contact	Lateral midfoot	8,0 ± 3,2	8,3 ± 3,3	0,847	-0,2
Begin of contact	Medial hindfoot	0,1 ± 0,4	0,0 ± 0,0	0,326	0,1
Begin of contact	Medial midfoot	9,4 ± 3,3	9,7 ± 4,3	0,800	-0,4
Begin of contact	MH1	13,4 ± 6,4	9,1 ± 5,9	0,069	4,3
Begin of contact	MH2	13,1 ± 5,3	10,5 ± 5,4	0,191	2,6
Begin of contact	MH3	8,6 ± 4,1	7,5 ± 3,5	0,420	1,1
Begin of contact	MH4	6,2 ± 3,3	7,3 ± 4,4	0,464	-1,1
Begin of contact	MH5	7,5 ± 4,4	14,6 ± 13,5	0,065	-7
Begin of contact	Toes 2345	33,8 ± 17,6	34,7 ± 14,4	0,876	-0,9
Begin of contact	Total object	0,0 ± 0,0	0,0 ± 0,0		0
Centre of pressure index (COPI)		1,27 ± 0,10	1,29 ± 0,14	0,593	-0,02
Coefficient of spreading		0,38 ± 0,02	0,39 ± 0,03	0,215	-0,01
Contact area	big toe	7,40 ± 1,64	7,33 ± 1,75	0,886	0,07
Contact area	Lateral hindfoot	11,67 ± 1,08	10,83 ± 1,49	0,048	0,84
Contact area	Lateral midfoot	16,03 ± 2,69	14,34 ± 3,12	0,062	1,7
Contact area	Medial hindfoot	11,40 ± 1,00	10,73 ± 1,37	0,087	0,67
Contact area	Medial midfoot	1,70 ± 1,05	1,22 ± 0,72	0,050	0,48
Contact area	MH1	8,20 ± 0,94	7,43 ± 1,44	0,056	0,77
Contact area	MH2	6,47 ± 0,61	6,67 ± 1,18	0,518	-0,21
Contact area	MH3	8,67 ± 1,03	7,89 ± 1,10	0,017	0,78
Contact area	MH4	7,27 ± 1,22	6,62 ± 1,06	0,051	0,64
Contact area	MH5	3,90 ± 0,81	3,47 ± 0,77	0,066	0,43
Contact area	Toes 2345	6,97 ± 1,20	7,39 ± 1,94	0,431	-0,42
Contact area	Total object	89,70 ± 7,68	84,06 ± 9,40	0,039	5,64
Contact area (LAMAI)		89,70 ± 7,68	89,07 ± 6,00	0,803	0,63
Contact area for MVP	big toe	5,23 ± 2,21	4,87 ± 1,53	0,601	0,37
Contact area for MVP	Lateral hindfoot	9,27 ± 1,21	9,50 ± 0,80	0,538	-0,23
Contact area for MVP	Lateral midfoot	11,10 ± 3,62	10,13 ± 3,71	0,476	0,97
Contact area for MVP	Medial hindfoot	9,53 ± 0,83	9,20 ± 0,92	0,308	0,33
Contact area for MVP	Medial midfoot	0,77 ± 0,70	0,47 ± 0,35	0,151	0,3
Contact area for MVP	MH1	6,37 ± 1,34	6,23 ± 0,86	0,749	0,13

Contact area for MVP	MH2	5,67 ± 0,56	6,10 ± 0,76	0,086	-0,43
Contact area for MVP	MH3	7,33 ± 1,01	7,47 ± 0,85	0,700	-0,13
Contact area for MVP	MH4	6,70 ± 1,13	6,57 ± 0,73	0,704	0,13
Contact area for MVP	MH5	3,00 ± 0,78	3,13 ± 0,64	0,613	-0,13
Contact area for MVP	Toes 2345	3,20 ± 1,26	3,33 ± 1,48	0,793	-0,13
Contact area for MVP	Total object	68,17 ± 8,02	67,03 ± 6,56	0,675	1,13
Contact time	big toe	542,4 ± 216,0	500,0 ± 124,5	0,515	42,4
Contact time	Lateral hindfoot	461,6 ± 152,7	442,4 ± 74,9	0,665	19,2
Contact time	Lateral midfoot	506,1 ± 146,1	506,1 ± 83,3	1,000	0
Contact time	Medial hindfoot	458,6 ± 152,3	447,5 ± 76,8	0,803	11,1
Contact time	Medial midfoot	339,4 ± 174,9	287,9 ± 138,7	0,379	51,5
Contact time	MH1	639,4 ± 160,1	645,5 ± 102,9	0,903	-6,1
Contact time	MH2	649,5 ± 167,0	647,5 ± 105,4	0,969	2
Contact time	MH3	682,8 ± 165,1	673,7 ± 101,6	0,857	9,1
Contact time	MH4	681,8 ± 161,9	664,6 ± 100,6	0,730	17,2
Contact time	MH5	617,2 ± 142,2	574,7 ± 144,5	0,424	42,4
Contact time	Toes 2345	521,2 ± 196,5	515,2 ± 169,1	0,929	6,1
Contact time	Total object	796,0 ± 185,3	776,8 ± 118,5	0,738	19,2
Contact time (p)	big toe	66,9 ± 18,2	60,6 ± 16,1	0,202	6,3
Contact time (p)	Lateral hindfoot	57,8 ± 9,4	56,1 ± 9,0	0,535	1,7
Contact time (p)	Lateral midfoot	63,7 ± 8,9	64,0 ± 10,2	0,917	-0,3
Contact time (p)	Medial hindfoot	57,6 ± 10,2	56,6 ± 9,0	0,726	1
Contact time (p)	Medial midfoot	41,2 ± 16,5	38,8 ± 13,0	0,557	2,4
Contact time (p)	MH1	80,2 ± 6,2	79,5 ± 8,5	0,773	0,7
Contact time (p)	MH2	81,4 ± 5,6	82,8 ± 6,0	0,426	-1,4
Contact time (p)	MH3	85,7 ± 4,0	84,8 ± 4,7	0,487	0,9
Contact time (p)	MH4	85,6 ± 3,1	84,2 ± 4,8	0,276	1,4
Contact time (p)	MH5	77,9 ± 5,8	73,6 ± 9,7	0,109	4,3
Contact time (p)	Toes 2345	65,0 ± 17,9	62,4 ± 16,2	0,589	2,7
Contact time (p)	Total object	100,0 ± 0,0	100,0 ± 0,0		0
Distance		21,1 ± 4,3	19,9 ± 0,8	0,268	1,3
End of contact	big toe	99,2 ± 1,2	98,9 ± 1,6	0,546	0,3
End of contact	Lateral hindfoot	57,8 ± 9,4	57,5 ± 7,9	0,922	0,3
End of contact	Lateral midfoot	71,7 ± 8,2	73,7 ± 6,4	0,460	-2
End of contact	Medial hindfoot	57,7 ± 10,1	58,0 ± 8,2	0,910	-0,4
End of contact	Medial midfoot	53,5 ± 10,8	52,3 ± 7,8	0,735	1,3
End of contact	MH1	93,5 ± 1,4	92,5 ± 2,6	0,167	1,1
End of contact	MH2	94,5 ± 1,7	94,0 ± 2,1	0,541	0,4
End of contact	MH3	94,3 ± 1,0	94,3 ± 1,4	0,952	0
End of contact	MH4	91,8 ± 2,5	92,9 ± 1,7	0,151	-1,1
End of contact	MH5	85,4 ± 4,4	87,6 ± 2,4	0,091	-2,3
End of contact	Toes 2345	98,8 ± 2,2	99,5 ± 1,1	0,288	-0,7
End of contact	Total object	100,0 ± 0,0	100,0 ± 0,0		0
Foot length		21,6 ± 1,2	21,4 ± 0,9	0,697	0,2
Foot progression angle		4,2 ± 4,8	3,1 ± 6,8	0,578	1,1
Force for MVP	big toe	16,6 ± 9,4	12,9 ± 9,6	0,289	3,7

Force for MVP	Lateral hindfoot	32,0 ± 9,4	34,6 ± 7,7	0,416	-2,6
Force for MVP	Lateral midfoot	17,6 ± 8,9	15,7 ± 6,7	0,507	1,9
Force for MVP	Medial hindfoot	36,8 ± 10,0	39,1 ± 9,5	0,532	-2,2
Force for MVP	Medial midfoot	1,2 ± 1,3	0,7 ± 0,8	0,244	0,5
Force for MVP	MH1	19,6 ± 7,4	17,7 ± 5,8	0,437	1,9
Force for MVP	MH2	26,2 ± 8,6	30,1 ± 9,9	0,260	-3,9
Force for MVP	MH3	35,9 ± 14,1	37,1 ± 12,7	0,800	-1,2
Force for MVP	MH4	26,7 ± 8,5	27,4 ± 6,2	0,776	-0,8
Force for MVP	MH5	9,7 ± 3,5	9,7 ± 3,3	0,979	0
Force for MVP	Toes 2345	6,4 ± 3,9	6,4 ± 4,7	0,958	-0,1
Force for MVP	Total object	228,7 ± 35,8	231,5 ± 39,5	0,838	-2,8
Force-time integral	big toe	13,7 ± 7,5	11,0 ± 9,0	0,376	2,7
Force-time integral	Lateral hindfoot	26,2 ± 10,5	27,0 ± 5,8	0,787	-0,8
Force-time integral	Lateral midfoot	15,9 ± 8,2	14,0 ± 5,8	0,463	1,9
Force-time integral	Medial hindfoot	29,6 ± 10,9	30,1 ± 5,6	0,868	-0,5
Force-time integral	Medial midfoot	1,2 ± 1,0	0,7 ± 0,9	0,181	0,5
Force-time integral	MH1	16,1 ± 6,9	14,4 ± 5,6	0,469	1,7
Force-time integral	MH2	21,6 ± 10,4	24,1 ± 10,1	0,500	-2,6
Force-time integral	MH3	30,1 ± 16,3	30,0 ± 13,4	0,990	0,1
Force-time integral	MH4	22,2 ± 11,1	21,7 ± 7,1	0,893	0,5
Force-time integral	MH5	7,9 ± 3,3	7,8 ± 3,1	0,920	0,1
Force-time integral	Toes 2345	6,2 ± 4,3	6,1 ± 4,3	0,936	0,1
Force-time integral	Total object	190,6 ± 65,6	187,0 ± 51,8	0,869	3,6
Force-time integral (normalized to BW)	big toe	4,1 ± 2,1	3,9 ± 2,5	0,868	0,2
Force-time integral (normalized to BW)	Lateral hindfoot	8,6 ± 2,1	6,9 ± 2,4	0,159	1,7
Force-time integral (normalized to BW)	Lateral midfoot	6,0 ± 1,7	5,0 ± 3,4	0,505	1
Force-time integral (normalized to BW)	Medial hindfoot	9,1 ± 0,8	7,3 ± 2,0	0,057	1,8
Force-time integral (normalized to BW)	Medial midfoot	0,4 ± 0,3	0,2 ± 0,2	0,178	0,2
Force-time integral (normalized to BW)	MH1	5,6 ± 1,7	4,1 ± 2,6	0,197	1,6
Force-time integral (normalized to BW)	MH2	9,3 ± 1,4	6,5 ± 2,0	0,006	2,8
Force-time integral (normalized to BW)	MH3	13,7 ± 1,8	8,0 ± 2,8	0,000	5,7
Force-time integral (normalized to BW)	MH4	9,4 ± 2,2	5,9 ± 2,4	0,004	3,5
Force-time integral (normalized to BW)	MH5	2,9 ± 0,9	2,2 ± 1,0	0,153	0,7
Force-time integral (normalized to BW)	Toes 2345	3,1 ± 0,9	2,5 ± 1,2	0,288	0,6
Force-time integral (normalized to BW)	Total object	72,2 ± 5,3	52,5 ± 7,9	0,000	19,8
Forefoot and heel coefficient		0,58 ± 0,03	0,58 ± 0,07	0,669	0,01
Forefoot angle		110,3 ± 3,0	113,4 ± 5,6	0,049	-3,1
Forefoot coefficient		1,06 ± 0,02	1,08 ± 0,04	0,082	-0,02
Forefoot width		8,1 ± 0,4	8,2 ± 0,7	0,924	0
Hallux angle		-5,2 ± 3,8	-2,2 ± 13,9	0,424	-2,9
Hallux angle (2)		-23,5 ± 6,9	1,3 ± 5,8	0,000	-24,9
Heel angle		14,8 ± 5,1	10,8 ± 6,5	0,038	4
Heel width		4,7 ± 0,2	4,7 ± 0,2	0,564	0,1
Instant of maximum force	big toe	81,1 ± 3,8	83,3 ± 4,6	0,094	-2,2
Instant of maximum force	Lateral hindfoot	26,0 ± 8,0	24,2 ± 4,9	0,307	1,7
Instant of maximum force	Lateral midfoot	47,6 ± 8,4	44,9 ± 9,3	0,319	2,7

Instant of maximum force	Medial hindfoot	22,8 ± 9,0	20,8 ± 6,7	0,355	2
Instant of maximum force	Medial midfoot	32,9 ± 9,2	29,1 ± 9,1	0,182	3,7
Instant of maximum force	MH1	65,7 ± 11,2	63,1 ± 14,4	0,538	2,5
Instant of maximum force	MH2	71,2 ± 8,9	74,4 ± 7,0	0,154	-3,2
Instant of maximum force	MH3	72,5 ± 7,7	72,7 ± 9,2	0,945	-0,2
Instant of maximum force	MH4	66,8 ± 9,9	66,7 ± 11,2	0,964	0,1
Instant of maximum force	MH5	64,8 ± 10,1	63,5 ± 10,3	0,678	1,3
Instant of maximum force	Toes 2345	84,4 ± 4,9	85,4 ± 4,5	0,465	-1
Instant of maximum force	Total object	54,4 ± 20,8	64,0 ± 19,5	0,105	-9,6
Instant of maximum velocity		96,4 ± 2,2	95,6 ± 2,1	0,294	0,8
Instant of peak pressure	big toe	78,5 ± 6,7	82,1 ± 5,8	0,044	-3,6
Instant of peak pressure	Lateral hindfoot	22,5 ± 9,0	19,5 ± 7,0	0,192	2,9
Instant of peak pressure	Lateral midfoot	42,8 ± 14,7	40,0 ± 13,8	0,508	2,7
Instant of peak pressure	Medial hindfoot	20,2 ± 10,2	18,3 ± 7,1	0,400	2
Instant of peak pressure	Medial midfoot	32,3 ± 12,5	25,7 ± 7,3	0,015	6,6
Instant of peak pressure	MH1	67,1 ± 12,5	67,1 ± 14,8	0,989	-0,1
Instant of peak pressure	MH2	79,7 ± 4,8	80,2 ± 4,6	0,719	-0,5
Instant of peak pressure	MH3	78,4 ± 5,9	78,4 ± 7,3	0,998	0
Instant of peak pressure	MH4	75,0 ± 7,7	73,3 ± 11,9	0,591	1,8
Instant of peak pressure	MH5	67,6 ± 9,2	64,2 ± 11,0	0,287	3,4
Instant of peak pressure	Toes 2345	82,8 ± 5,4	85,6 ± 4,2	0,037	-2,8
Instant of peak pressure	Total object	59,8 ± 26,3	63,8 ± 27,9	0,623	-4
Lateral contact area		50,07 ± 4,23	47,16 ± 5,38	0,060	2,9
Lateral force-time integral		101,1 ± 40,3	80,4 ± 24,4	0,018	20,7
Lateral plantar angle		8,3 ± 0,7	8,1 ± 1,4	0,709	0,1
Lateral tarsal angle		152,5 ± 4,4	154,9 ± 4,5	0,076	-2,4
Lateral-medial area index (LAMAI)		0,12 ± 0,04	0,12 ± 0,05	0,677	-0,01
Lateral-medial force index		1,14 ± 0,34	1,17 ± 0,40	0,782	-0,03
Lateral-medial force-time integral index		11,5 ± 29,5	12,6 ± 19,4	0,900	-1,2
Long plantar angle (g)		16,5 ± 1,3	17,2 ± 1,4	0,175	-0,7
Long plantar angle (p)		16,5 ± 1,3	16,3 ± 2,7	0,709	0,3
Maximum force	big toe	53,9 ± 19,8	41,6 ± 18,7	0,090	12,4
Maximum force	Lateral hindfoot	103,5 ± 22,8	104,4 ± 13,5	0,896	-0,9
Maximum force	Lateral midfoot	60,3 ± 22,9	58,2 ± 15,6	0,768	2,1
Maximum force	Medial hindfoot	119,0 ± 15,9	117,1 ± 15,4	0,747	1,9
Maximum force	Medial midfoot	5,7 ± 4,1	3,3 ± 3,0	0,082	2,4
Maximum force	MH1	48,3 ± 11,9	43,9 ± 12,9	0,348	4,3
Maximum force	MH2	61,1 ± 15,3	66,1 ± 19,3	0,435	-5
Maximum force	MH3	81,9 ± 27,4	83,3 ± 25,4	0,887	-1,4
Maximum force	MH4	61,8 ± 19,6	62,0 ± 13,8	0,981	-0,1
Maximum force	MH5	24,9 ± 7,0	25,2 ± 6,8	0,900	-0,3
Maximum force	Toes 2345	26,5 ± 9,2	23,9 ± 10,6	0,481	2,6
Maximum force	Total object	332,5 ± 55,9	327,2 ± 57,5	0,801	5,3
Maximum force (normalized to BW)	big toe	15,4 ± 7,2	19,8 ± 7,6	0,240	-4,4
Maximum force (normalized to BW)	Lateral hindfoot	31,9 ± 6,2	33,2 ± 8,4	0,742	-1,3
Maximum force (normalized to BW)	Lateral midfoot	20,8 ± 4,9	20,8 ± 11,6	0,993	0
Maximum force (normalized to BW)	Medial hindfoot	34,8 ± 2,1	36,3 ± 8,4	0,684	-1,6
Maximum force (normalized to BW)	Medial midfoot	1,7 ± 0,7	1,3 ± 1,1	0,367	0,5
Maximum force (normalized to BW)	MH1	13,2 ± 2,7	14,2 ± 7,0	0,759	-1
Maximum force (normalized to BW)	MH2	20,2 ± 2,0	21,9 ± 4,4	0,400	-1,7
Maximum force (normalized to BW)	MH3	30,3 ± 4,0	26,3 ± 6,4	0,183	4
Maximum force (normalized to BW)	MH4	21,5 ± 3,4	19,2 ± 5,6	0,383	2,3
Maximum force (normalized to BW)	MH5	7,4 ± 2,1	7,9 ± 3,2	0,741	-0,5
Maximum force (normalized to BW)	Toes 2345	10,1 ± 0,9	12,9 ± 4,3	0,162	-2,8
Maximum force (normalized to BW)	Total object	107,1 ± 1,5	109,8 ± 3,6	0,118	-2,7
Maximum mean pressure	big toe	56,7 ± 33,8	42,0 ± 20,9	0,165	14,7

Maximum mean pressure	Lateral hindfoot	58.7 ± 16.6	64.7 ± 16.2	0.325	-6
Maximum mean pressure	Lateral midfoot	23.7 ± 9.5	23.3 ± 6.5	0.912	0.3
Maximum mean pressure	Medial hindfoot	66.3 ± 17.8	73.3 ± 17.5	0.286	-7
Maximum mean pressure	Medial midfoot	14.3 ± 9.4	11.3 ± 8.3	0.364	3
Maximum mean pressure	MH1	51.3 ± 16.7	44.7 ± 9.5	0.191	6.7
Maximum mean pressure	MH2	76.3 ± 23.9	81.0 ± 22.2	0.584	-4.7
Maximum mean pressure	MH3	79.7 ± 23.4	88.0 ± 19.9	0.302	-8.3
Maximum mean pressure	MH4	68.3 ± 12.5	72.7 ± 15.0	0.397	-4.3
Maximum mean pressure	MH5	54.0 ± 17.1	51.3 ± 19.7	0.695	2.7
Maximum mean pressure	Toes 2345	32.7 ± 15.7	32.3 ± 20.4	0.960	0.3
Maximum mean pressure	Total object	97.0 ± 14.9	96.0 ± 16.5	0.863	1
Maximum velocity		1.05 ± 0.35	1.26 ± 0.36	0.133	-0.2
Mean pressure	big toe	74.7 ± 23.2	81.0 ± 31.3	0.471	-6.3
Mean pressure	Lateral hindfoot	95.0 ± 17.0	101.4 ± 21.2	0.287	-6.4
Mean pressure	Lateral midfoot	41.9 ± 13.3	40.1 ± 14.4	0.676	1.7
Mean pressure	Medial hindfoot	111.2 ± 16.8	116.1 ± 29.3	0.540	-4.9
Mean pressure	Medial midfoot	30.6 ± 11.3	27.7 ± 10.6	0.362	2.9
Mean pressure	MH1	61.1 ± 12.0	60.7 ± 24.1	0.952	0.4
Mean pressure	MH2	104.3 ± 26.1	102.2 ± 21.9	0.757	2.1
Mean pressure	MH3	105.3 ± 27.0	105.7 ± 23.6	0.955	-0.4
Mean pressure	MH4	93.7 ± 23.6	92.2 ± 25.8	0.841	1.5
Mean pressure	MH5	68.8 ± 17.8	67.5 ± 24.0	0.842	1.3
Mean pressure	Toes 2345	39.9 ± 10.2	46.4 ± 11.7	0.060	-6.4
Mean pressure	Total object	78.1 ± 9.9	80.7 ± 10.1	0.391	-2.6
Mean pressure for MVP	big toe	28.2 ± 13.6	24.3 ± 11.2	0.399	3.9
Mean pressure for MVP	Lateral hindfoot	34.3 ± 8.6	36.4 ± 7.9	0.483	-2.1
Mean pressure for MVP	Lateral midfoot	15.2 ± 4.8	15.0 ± 2.8	0.890	0.2
Mean pressure for MVP	Medial hindfoot	38.5 ± 9.8	42.7 ± 10.6	0.269	-4.2
Mean pressure for MVP	Medial midfoot	12.3 ± 6.3	10.9 ± 7.4	0.583	1.4
Mean pressure for MVP	MH1	30.0 ± 7.7	27.7 ± 6.3	0.387	2.3
Mean pressure for MVP	MH2	45.9 ± 12.4	48.5 ± 11.4	0.547	-2.7
Mean pressure for MVP	MH3	48.2 ± 14.7	49.1 ± 13.0	0.855	-0.9
Mean pressure for MVP	MH4	39.4 ± 8.9	41.8 ± 8.2	0.450	-2.4
Mean pressure for MVP	MH5	32.4 ± 8.3	30.7 ± 7.1	0.553	1.7
Mean pressure for MVP	Toes 2345	18.5 ± 4.7	17.2 ± 6.4	0.520	1.3
Mean pressure for MVP	Total object	33.6 ± 3.6	34.5 ± 4.5	0.536	-0.9
Mean velocity		0.28 ± 0.05	0.27 ± 0.05	0.546	0.01
Medial contact area		39.63 ± 4.05	38.97 ± 2.38	0.587	0.67
Medial force-time integral		89.6 ± 31.1	72.7 ± 30.0	0.064	16.8
Medial plantar angle		8.3 ± 0.7	8.1 ± 1.4	0.709	0.1
Medial tarsal angle		145.8 ± 2.4	146.0 ± 3.6	0.866	-0.2
Peak mean pressure	big toe	78.8 ± 23.9	63.4 ± 16.3	0.049	15.4
Peak mean pressure	Lateral hindfoot	96.9 ± 16.6	96.2 ± 9.1	0.892	0.7
Peak mean pressure	Lateral midfoot	39.9 ± 12.6	39.2 ± 7.1	0.861	0.7
Peak mean pressure	Medial hindfoot	112.9 ± 15.0	116.3 ± 15.8	0.552	-3.4
Peak mean pressure	Medial midfoot	34.4 ± 12.4	30.7 ± 14.6	0.463	3.7
Peak mean pressure	MH1	65.8 ± 12.6	59.7 ± 14.4	0.227	6.1
Peak mean pressure	MH2	107.6 ± 26.0	113.5 ± 27.7	0.553	-5.9
Peak mean pressure	MH3	118.2 ± 30.2	124.4 ± 27.5	0.559	-6.2
Peak mean pressure	MH4	90.7 ± 21.9	96.7 ± 14.2	0.386	-5.9
Peak mean pressure	MH5	72.1 ± 15.0	77.0 ± 22.7	0.495	-4.9
Peak mean pressure	Toes 2345	42.2 ± 10.7	38.5 ± 10.7	0.357	3.7
Peak mean pressure	Total object	81.1 ± 8.3	80.1 ± 8.6	0.754	1
Peak pressure	big toe	167.7 ± 61.7	204.7 ± 149.7	0.356	-37
Peak pressure	Lateral hindfoot	183.3 ± 37.8	195.0 ± 59.4	0.477	-11.7

Peak pressure	Lateral midfoot	73.7 ± 24.4	80.9 ± 33.0	0.434	-7.3
Peak pressure	Medial hindfoot	209.3 ± 41.5	215.8 ± 68.7	0.731	-6.5
Peak pressure	Medial midfoot	49.0 ± 22.2	41.0 ± 19.8	0.189	8
Peak pressure	MH1	115.7 ± 22.8	107.9 ± 45.6	0.527	7.8
Peak pressure	MH2	183.0 ± 49.7	186.6 ± 42.8	0.783	-3.6
Peak pressure	MH3	192.0 ± 47.3	192.8 ± 40.8	0.952	-0.8
Peak pressure	MH4	167.0 ± 27.0	159.7 ± 51.8	0.603	7.3
Peak pressure	MH5	132.0 ± 38.4	121.9 ± 57.4	0.528	10.1
Peak pressure	Toes 2345	117.0 ± 54.4	127.4 ± 51.7	0.501	-10.4
Peak pressure	Total object	232.7 ± 24.4	274.1 ± 123.7	0.204	-41.4
Posterior plantar angle		30.7 ± 2.4	29.4 ± 2.2	0.052	1.3
Pressure-time integral	big toe	47.5 ± 25.0	44.8 ± 41.1	0.815	2.6
Pressure-time integral	Lateral hindfoot	49.2 ± 20.5	43.4 ± 13.7	0.214	5.8
Pressure-time integral	Lateral midfoot	24.3 ± 11.5	22.6 ± 10.5	0.602	1.7
Pressure-time integral	Medial hindfoot	55.2 ± 22.5	47.6 ± 15.4	0.141	7.6
Pressure-time integral	Medial midfoot	12.3 ± 7.9	8.1 ± 5.3	0.020	4.2
Pressure-time integral	MH1	42.3 ± 14.8	33.4 ± 15.7	0.055	8.9
Pressure-time integral	MH2	63.2 ± 29.7	53.2 ± 18.1	0.115	10
Pressure-time integral	MH3	67.5 ± 30.5	56.2 ± 18.0	0.080	11.3
Pressure-time integral	MH4	58.3 ± 19.0	47.1 ± 16.3	0.030	11.1
Pressure-time integral	MH5	42.8 ± 13.9	34.1 ± 16.1	0.065	8.7
Pressure-time integral	Toes 2345	29.6 ± 20.1	26.8 ± 17.3	0.612	2.7
Pressure-time integral	Total object	119.7 ± 34.4	111.7 ± 37.7	0.468	8
Subarch angle		102.6 ± 8.5	104.2 ± 6.7	0.469	-1.6
Transverse plantar angle		17.2 ± 10.6	23.0 ± 14.4	0.153	-5.8
|Ar-Al|		6.13 ± 3.49	3.49 ± 2.40	0.023	2.64

8.4 Measurement results Cross-bite group

12 - biss 1 li 13 - biss 1 re Parameter	Mask	Left foot Value 1 (L)	Right foot Value 2	P	Diff.
Anterior plantar angle		29.3 ± 2.3	29.7 ± 2.1	0.23819	-0.4
Ar+Al		10.82 ± 5.64	11.35 ± 4.55	0.52448	-0.53
Arch index		0.19 ± 0.07	0.22 ± 0.05	0.00084	-0.03
Area between the axis and gait line (Ar)		7,70 ± 5,25	3.93 ± 3.61	9.3E-07	3.77
Area between the gait line and axis (Al)		3,13 ± 3,75	7.43 ± 3.69	5.4E-11	-4.3
Average mean pressure	big toe	43.9 ± 16.2	42.4 ± 17.7	0.58982	1.5
Average mean pressure	hindfoot	72.3 ± 18.9	66.5 ± 18.7	0.0616	5.8
Average mean pressure	Lateral forefoot	47.8 ± 12.9	52.7 ± 12.8	0.02174	-5
Average mean pressure	Lateral hindfoot	67.8 ± 19.3	63.3 ± 18.0	0.15302	4.4
Average mean pressure	Lateral midfoot	25.0 ± 6.9	27.6 ± 8.5	0.04035	-2.6
Average mean pressure	Medial forefoot	45.1 ± 13.8	41.1 ± 14.6	0.09561	4
Average mean pressure	Medial hindfoot	78.5 ± 19.6	72.0 ± 20.4	0.05183	6.5
Average mean pressure	Medial midfoot	25.3 ± 7.1	24.5 ± 8.2	0.49507	0.9
Average mean pressure	MH1	44.9 ± 13.7	41.7 ± 13.9	0.15505	3.2

Average mean pressure	MH2	58.6 ± 19.8	62.0 ± 17.7	0.26858	-3.4
Average mean pressure	MH3	57.8 ± 16.6	61.5 ± 15.5	0.16547	-3.7
Average mean pressure	MH4	43.9 ± 12.2	48.8 ± 13.3	0.02048	-4.9
Average mean pressure	MH5	36.5 ± 13.5	41.2 ± 15.5	0.05006	-4.7
Average mean pressure	midfoot	25.5 ± 6.6	27.7 ± 7.9	0.06822	-2.2
Average mean pressure	Toes 2345	23.9 ± 6.0	24.9 ± 7.2	0.35284	-1
Average mean pressure	Total object	57.6 ± 10.9	57.2 ± 9.7	0.77656	0.5
Begin of contact	big toe	30.0 ± 18.3	34.1 ± 17.8	0.18328	-4.1
Begin of contact	hindfoot	0.5 ± 1.9	0.8 ± 2.7	0.4409	-0.3
Begin of contact	Lateral forefoot	9.2 ± 5.7	8.6 ± 6.1	0.60837	0.5
Begin of contact	Lateral hindfoot	0.7 ± 1.9	1.0 ± 2.9	0.49802	-0.3
Begin of contact	Lateral midfoot	9.5 ± 4.1	8.8 ± 4.7	0.37736	0.6
Begin of contact	Medial forefoot	15.2 ± 8.9	14.7 ± 9.9	0.75652	0.5
Begin of contact	Medial hindfoot	0.5 ± 1.9	0.9 ± 2.8	0.34706	-0.4
Begin of contact	Medial midfoot	11.8 ± 5.6	11.5 ± 6.8	0.75431	0.3
Begin of contact	MH1	15.1 ± 8.8	14.4 ± 9.5	0.61472	0.8
Begin of contact	MH2	13.2 ± 6.4	11.5 ± 6.8	0.11267	1.7
Begin of contact	MH3	11.5 ± 6.7	9.9 ± 6.1	0.11677	1.7
Begin of contact	MH4	10.3 ± 5.7	9.1 ± 6.1	0.23231	1.2
Begin of contact	MH5	13.4 ± 10.1	12.5 ± 8.6	0.57607	0.9
Begin of contact	midfoot	9.3 ± 3.9	8.4 ± 4.8	0.17754	1
Begin of contact	Toes 2345	40.6 ± 17.4	35.3 ± 14.7	0.04757	5.3
Begin of contact	Total object	0.0 ± 0.0	0.0 ± 0.0		0
Centre of pressure index (COPI)		1,19 ± 0,17	1.21 ± 0.16	0.4589	-0.02
Coefficient of spreading		0.39 ± 0.03	0.40 ± 0.03	0.77533	0
Contact area	big toe	7.38 ± 2.32	7.21 ± 2.49	0.66015	0.17
Contact area	hindfoot	22.39 ± 4.61	22.43 ± 4.63	0.95777	-0.04
Contact area	Lateral forefoot	18.64 ± 4.62	19.17 ± 4.36	0.47299	-0.54
Contact area	Lateral hindfoot	11.12 ± 2.43	11.06 ± 2.50	0.88214	0.06
Contact area	Lateral midfoot	12.22 ± 6.58	15.01 ± 5.53	0.00641	-2.79
Contact area	Medial forefoot	9.20 ± 2.76	9.13 ± 3.26	0.89439	0.07
Contact area	Medial hindfoot	11.20 ± 2.32	11.28 ± 2.44	0.82773	-0.09
Contact area	Medial midfoot	1.99 ± 1.55	2.09 ± 2.24	0.74533	-0.1
Contact area	MH1	8.63 ± 2.46	8.79 ± 2.41	0.67555	-0.17
Contact area	MH2	7.45 ± 1.80	7.75 ± 1.96	0.33038	-0.3
Contact area	MH3	8.47 ± 2.17	8.76 ± 2.08	0.39931	-0.29
Contact area	MH4	7.24 ± 1.53	7.11 ± 1.60	0.62039	0.13
Contact area	MH5	4.06 ± 1.26	3.97 ± 1.13	0.65842	0.09
Contact area	midfoot	14.36 ± 7.20	17.13 ± 6.49	0.0146	-2.77
Contact area	Toes 2345	7.52 ± 2.76	7.37 ± 2.70	0.74265	0.15
Contact area	Total object	87.81 ± 19.96	90.71 ± 20.29	0.3779	-2.91

Contact area (LAMAI)		87.81 ± 19.96	90.71 ± 20.29	0.3779	-2.91
Contact area for MVP	big toe	5.42 ± 2.04	5.09 ± 2.29	0.34782	0.33
Contact area for MVP	hindfoot	17.99 ± 4.00	17.66 ± 4.50	0.6392	0.33
Contact area for MVP	Lateral forefoot	15.75 ± 4.43	16.66 ± 4.06	0.20118	-0.91
Contact area for MVP	Lateral hindfoot	8.87 ± 2.29	8.81 ± 2.48	0.87142	0.06
Contact area for MVP	Lateral midfoot	6.69 ± 6.32	9.46 ± 6.43	0.00993	-2.77
Contact area for MVP	Medial forefoot	7.43 ± 2.54	6.99 ± 3.14	0.35679	0.44
Contact area for MVP	Medial hindfoot	9.10 ± 2.03	8.85 ± 2.43	0.50501	0.25
Contact area for MVP	Medial midfoot	0.87 ± 0.81	0.85 ± 1.06	0.88489	0.02
Contact area for MVP	MH1	6.93 ± 2.23	6.76 ± 2.53	0.65712	0.17
Contact area for MVP	MH2	6.31 ± 1.62	6.48 ± 1.57	0.50742	-0.17
Contact area for MVP	MH3	7.24 ± 2.02	7.75 ± 1.86	0.11295	-0.51
Contact area for MVP	MH4	6.31 ± 1.61	6.43 ± 1.63	0.66911	-0.11
Contact area for MVP	MH5	3.04 ± 1.21	3.03 ± 0.91	0.93935	0.01
Contact area for MVP	midfoot	7.68 ± 6.53	10.28 ± 6.70	0.01735	-2.6
Contact area for MVP	Toes 2345	3.42 ± 1.95	3.65 ± 1.70	0.43611	-0.23
Contact area for MVP	Total object	64.51 ± 16.82	67.18 ± 17.57	0.34394	-2.67
Contact time	big toe	442.4 ± 176.5	436.6 ± 207.4	0.85248	5.9
Contact time	hindfoot	399.0 ± 89.4	383.2 ± 109.5	0.33604	15.8
Contact time	Lateral forefoot	581.2 ± 80.8	609.0 ± 119.7	0.10229	-27.9
Contact time	Lateral hindfoot	392.7 ± 92.3	379.8 ± 111.6	0.45071	12.9
Contact time	Lateral midfoot	398.3 ± 116.9	430.6 ± 114.7	0.09569	-32.3
Contact time	Medial forefoot	522.8 ± 87.7	550.3 ± 117.9	0.11344	-27.5
Contact time	Medial hindfoot	396.2 ± 89.7	383.4 ± 110.5	0.44461	12.8
Contact time	Medial midfoot	287.9 ± 95.9	274.6 ± 122.2	0.46827	13.3
Contact time	MH1	518.8 ± 86.6	555.6 ± 122.2	0.03521	-36.8
Contact time	MH2	549.3 ± 81.3	588.5 ± 115.8	0.01774	-39.2
Contact time	MH3	562.6 ± 82.9	599.6 ± 117.2	0.02721	-37
Contact time	MH4	561.4 ± 78.6	589.7 ± 113.6	0.07822	-28.3
Contact time	MH5	497.8 ± 96.3	513.3 ± 119.2	0.38082	-15.6
Contact time	midfoot	401.6 ± 113.6	433.5 ± 111.9	0.08501	-31.9
Contact time	Toes 2345	390.7 ± 146.9	442.2 ± 175.7	0.05327	-51.5
Contact time	Total object	676.6 ± 90.4	708.3 ± 117.5	0.06588	-31.7
Contact time (p)	big toe	65.2 ± 23.7	60.6 ± 23.8	0.23275	4.6
Contact time (p)	hindfoot	58.9 ± 9.9	54.0 ± 11.0	0.00439	4.9

Contact time (p)	Lateral forefoot	85.7 ± 5.4	85.5 ± 6.5	0.86428	0.2
Contact time (p)	Lateral hindfoot	57.7 ± 10.0	53.3 ± 11.3	0.01421	4.4
Contact time (p)	Lateral midfoot	58.2 ± 13.6	60.3 ± 9.0	0.29574	-2
Contact time (p)	Medial forefoot	77.1 ± 9.3	77.3 ± 9.8	0.88473	-0.2
Contact time (p)	Medial hindfoot	58.3 ± 9.9	53.8 ± 11.2	0.01148	4.5
Contact time (p)	Medial midfoot	42.3 ± 12.2	38.4 ± 14.1	0.07435	3.9
Contact time (p)	MH1	76.9 ± 9.5	78.4 ± 9.8	0.33228	-1.5
Contact time (p)	MH2	81.3 ± 6.6	83.1 ± 7.4	0.11486	-1.8
Contact time (p)	MH3	83.3 ± 7.0	84.6 ± 6.6	0.25521	-1.3
Contact time (p)	MH4	83.1 ± 6.0	83.3 ± 7.1	0.89505	-0.1
Contact time (p)	MH5	73.6 ± 10.7	72.5 ± 10.7	0.52864	1.1
Contact time (p)	midfoot	59.1 ± 13.4	61.0 ± 9.2	0.29087	-2
Contact time (p)	Toes 2345	57.5 ± 19.7	61.6 ± 19.3	0.19911	-4.1
Contact time (p)	Total object	100.0 ± 0.0	100.0 ± 0.0		0
Distance		20.3 ± 3.1	20.0 ± 2.7	0.50461	0.3
End of contact	big toe	98.9 ± 1.3	99.0 ± 1.2	0.73948	-0.1
End of contact	hindfoot	59.4 ± 10.0	54.8 ± 10.4	0.00608	4.6
End of contact	Lateral forefoot	94.8 ± 1.8	94.1 ± 2.0	0.03395	0.7
End of contact	Lateral hindfoot	58.3 ± 10.2	54.2 ± 10.6	0.0185	4.1
End of contact	Lateral midfoot	67.7 ± 12.5	69.1 ± 8.1	0.43703	-1.4
End of contact	Medial forefoot	92.3 ± 5.6	92.1 ± 4.3	0.75932	0.3
End of contact	Medial hindfoot	58.8 ± 10.1	54.7 ± 10.5	0.01738	4.1
End of contact	Medial midfoot	54.1 ± 10.3	50.9 ± 10.4	0.06863	3.2
End of contact	MH1	92.0 ± 5.9	92.8 ± 3.9	0.33959	-0.8
End of contact	MH2	94.5 ± 2.1	94.6 ± 2.2	0.80751	-0.1
End of contact	MH3	94.8 ± 1.9	94.4 ± 2.1	0.23695	0.4
End of contact	MH4	93.4 ± 2.3	92.4 ± 3.1	0.02635	1
End of contact	MH5	87.0 ± 5.7	85.0 ± 6.7	0.05588	2
End of contact	midfoot	68.4 ± 12.5	69.4 ± 8.1	0.54971	-1
End of contact	Toes 2345	99.8 ± 0.8	99.5 ± 1.0	0.11891	0.2
End of contact	Total object	100.0 ± 0.0	100.0 ± 0.0		0
Foot length		21.1 ± 2.3	21.0 ± 2.3	0.81597	0.1
Foot progression angle		1.4 ± 6.4	3.5 ± 5.1	0.03134	-2.1
Force for MVP	big toe	17.7 ± 11.1	15.6 ± 10.5	0.2546	2
Force for MVP	hindfoot	77.7 ± 34.4	66.3 ± 31.8	0.03712	11.4
Force for MVP	Lateral forefoot	58.7 ± 29.4	67.8 ± 29.7	0.0643	-9.1
Force for MVP	Lateral hindfoot	35.9 ± 18.6	31.1 ± 16.0	0.10237	4.7
Force for MVP	Lateral midfoot	12.0 ± 13.8	17.2 ± 14.6	0.02878	-5.2
Force for MVP	Medial forefoot	26.3 ± 14.4	24.0 ± 17.6	0.39816	2.3
Force for MVP	Medial hindfoot	42.2 ± 17.6	36.1 ± 17.6	0.04124	6
Force for MVP	Medial midfoot	1.4 ± 1.5	1.4 ± 1.8	0.85761	0

Force for MVP	MH1	24.5 ± 12.9	22.8 ± 14.5	0.4672	1.6
Force for MVP	MH2	29.3 ± 14.5	32.5 ± 15.5	0.18912	-3.2
Force for MVP	MH3	32.8 ± 14.5	36.6 ± 14.3	0.10588	-3.8
Force for MVP	MH4	21.6 ± 9.7	23.9 ± 9.6	0.15411	-2.3
Force for MVP	MH5	8.6 ± 6.2	9.2 ± 5.4	0.50991	-0.6
Force for MVP	midfoot	13.6 ± 14.1	18.4 ± 14.8	0.04398	-4.8
Force for MVP	Toes 2345	5.7 ± 4.0	6.5 ± 3.9	0.18694	-0.9
Force for MVP	Total object	231.7 ± 76.2	232.0 ± 73.8	0.97941	-0.3
Force-time integral	big toe	12.3 ± 8.0	11.5 ± 8.0	0.53057	0.8
Force-time integral	hindfoot	53.2 ± 24.0	47.3 ± 22.5	0.11957	5.9
Force-time integral	Lateral forefoot	40.7 ± 21.0	48.4 ± 20.9	0.02781	-7.7
Force-time integral	Lateral hindfoot	24.7 ± 12.7	22.3 ± 11.3	0.21621	2.5
Force-time integral	Lateral midfoot	9.7 ± 9.9	13.9 ± 10.8	0.01492	-4.2
Force-time integral	Medial forefoot	18.2 ± 10.4	17.3 ± 12.9	0.65463	0.9
Force-time integral	Medial hindfoot	28.8 ± 12.3	25.8 ± 12.2	0.13645	3
Force-time integral	Medial midfoot	1.2 ± 1.2	1.2 ± 1.4	0.97053	0
Force-time integral	MH1	16.8 ± 9.3	16.3 ± 10.4	0.75746	0.5
Force-time integral	MH2	20.0 ± 10.1	23.1 ± 11.0	0.06858	-3.2
Force-time integral	MH3	22.5 ± 10.6	26.0 ± 9.9	0.04281	-3.4
Force-time integral	MH4	14.9 ± 7.0	17.0 ± 7.0	0.07015	-2.1
Force-time integral	MH5	6.1 ± 4.5	6.7 ± 3.8	0.40278	-0.6
Force-time integral	midfoot	10.9 ± 10.2	14.9 ± 11.0	0.02231	-4
Force-time integral	Toes 2345	4.7 ± 3.1	5.5 ± 3.3	0.14208	-0.8
Force-time integral	Total object	161.8 ± 57.9	168.4 ± 55.7	0.47816	-6.6
Force-time integral (normalized to BW)	big toe	4.5 ± 3.2	4.0 ± 2.9	0.34702	0.5
Force-time integral (normalized to BW)	hindfoot	17.6 ± 5.4	15.8 ± 6.4	0.07125	1.7
Force-time integral (normalized to BW)	Lateral forefoot	13.6 ± 5.5	16.5 ± 6.4	0.004	-2.9
Force-time integral (normalized to BW)	Lateral hindfoot	8.0 ± 2.8	7.3 ± 3.3	0.19025	0.7
Force-time integral (normalized to BW)	Lateral midfoot	3.0 ± 2.7	4.4 ± 3.2	0.00382	-1.5
Force-time integral (normalized to BW)	Medial forefoot	6.0 ± 2.8	5.5 ± 3.4	0.35505	0.5
Force-time integral (normalized to BW)	Medial hindfoot	9.6 ± 3.1	8.5 ± 3.5	0.05372	1.1
Force-time integral (normalized to BW)	Medial midfoot	0.4 ± 0.4	0.4 ± 0.4	0.78898	0
Force-time integral (normalized to BW)	MH1	5.6 ± 2.5	5.4 ± 3.0	0.76955	0.1
Force-time integral (normalized to BW)	MH2	6.5 ± 2.2	7.6 ± 2.2	0.0023	-1.1
Force-time integral (normalized to BW)	MH3	7.5 ± 2.7	8.9 ± 2.7	0.00218	-1.4
Force-time integral (normalized to BW)	MH4	5.1 ± 2.2	5.9 ± 2.4	0.03347	-0.8
Force-time integral (normalized to BW)	MH5	2.0 ± 1.4	2.3 ± 1.3	0.2067	-0.3
Force-time integral (normalized to BW)	midfoot	3.5 ± 2.9	4.9 ± 3.3	0.00581	-1.4
Force-time integral (normalized to BW)	Toes 2345	1.7 ± 1.2	1.9 ± 1.3	0.21478	-0.2

Force-time integral (normalized to BW)	Total object	54.0 ± 7.7	56.8 ± 9.8	0.05251	-2.8
Forefoot and heel coefficient		0,57 ± 0,05	0.57 ± 0.06	0.70365	0
Forefoot angle		112.6 ± 11.7	113.5 ± 5.9	0.53812	-0.9
Forefoot coefficient		1.08 ± 0.06	1.08 ± 0.04	0.67543	0
Forefoot width		8.3 ± 1.0	8.3 ± 1.0	0.95188	0
Hallux angle		-4.0 ± 14.3	-6.2 ± 11.4	0.32329	2.2
Hallux angle (2)		-20.7 ± 15.2	2.5 ± 10.1	5.6E-16	-23.2
Heel angle		12.6 ± 5.5	11.4 ± 6.3	0.26276	1.2
Heel width		4.7 ± 0.5	4.7 ± 0.5	0.69412	0
Instant of maximum force	big toe	80.2 ± 12.0	82.2 ± 7.7	0.25074	-2
Instant of maximum force	hindfoot	23.6 ± 7.0	21.9 ± 6.2	0.13165	1.6
Instant of maximum force	Lateral forefoot	68.6 ± 10.9	67.4 ± 9.4	0.48223	1.2
Instant of maximum force	Lateral hindfoot	24.2 ± 7.3	23.1 ± 6.1	0.29362	1.2
Instant of maximum force	Lateral midfoot	44.8 ± 13.8	42.4 ± 10.6	0.23869	2.4
Instant of maximum force	Medial forefoot	65.3 ± 13.2	62.8 ± 17.6	0.32405	2.5
Instant of maximum force	Medial hindfoot	22.7 ± 8.1	20.9 ± 6.7	0.14688	1.8
Instant of maximum force	Medial midfoot	34.5 ± 12.6	30.0 ± 8.1	0.0116	4.5
Instant of maximum force	MH1	65.4 ± 13.3	63.8 ± 16.3	0.50808	1.6
Instant of maximum force	MH2	73.6 ± 9.7	74.6 ± 5.2	0.41405	-1
Instant of maximum force	MH3	75.0 ± 7.1	72.2 ± 8.4	0.02966	2.8
Instant of maximum force	MH4	67.8 ± 11.3	66.5 ± 9.5	0.47114	1.2
Instant of maximum force	MH5	63.6 ± 13.9	60.6 ± 11.8	0.15647	3
Instant of maximum force	midfoot	44.0 ± 13.7	41.5 ± 10.5	0.21147	2.5
Instant of maximum force	Toes 2345	85.4 ± 3.3	85.4 ± 3.0	0.9626	0
Instant of maximum force	Total object	55.6 ± 24.2	55.2 ± 23.7	0.90806	0.5
Instant of maximum velocity		69,1 ± 38,7	70.4 ± 36.6	0.83829	-1.3
Instant of peak pressure	big toe	76.6 ± 15.1	80.4 ± 8.5	0.06424	-3.9
Instant of peak pressure	hindfoot	19.8 ± 8.6	18.5 ± 7.5	0.31699	1.3
Instant of peak pressure	Lateral forefoot	78.1 ± 8.4	76.5 ± 8.7	0.24782	1.6
Instant of peak pressure	Lateral hindfoot	20.4 ± 8.1	19.4 ± 7.1	0.43244	1
Instant of peak pressure	Lateral midfoot	37.5 ± 15.9	38.1 ± 13.5	0.80116	-0.6
Instant of peak pressure	Medial forefoot	67.4 ± 15.2	66.9 ± 16.8	0.85197	0.5
Instant of peak pressure	Medial hindfoot	20.0 ± 8.7	18.8 ± 7.5	0.38409	1.2
Instant of peak pressure	Medial midfoot	28.5 ± 9.5	26.6 ± 6.6	0.18517	1.8
Instant of peak pressure	MH1	66.2 ± 15.7	68.7 ± 14.8	0.33014	-2.4
Instant of peak pressure	MH2	78.5 ± 8.7	79.2 ± 5.2	0.54701	-0.7
Instant of peak pressure	MH3	79.7 ± 6.6	79.0 ± 5.8	0.48427	0.7
Instant of peak pressure	MH4	73.6 ± 12.2	71.9 ± 11.5	0.36173	1.8
Instant of peak pressure	MH5	64.1 ± 15.9	62.7 ± 11.9	0.54578	1.4
Instant of peak pressure	midfoot	36.5 ± 16.0	38.3 ± 13.9	0.47366	-1.8
Instant of peak pressure	Toes 2345	82.7 ± 7.3	84.2 ± 4.2	0.13539	-1.5
Instant of peak pressure	Total object	44.0 ± 30.4	62.2 ± 28.3	0.0002	-18.3
Lateral contact area		47.80 ± 12.40	49.73 ± 12.45	0.34387	-1.93

Lateral force-time integral		78.4 ± 33.1	85.6 ± 31.4	0.17055	-7.2
Lateral plantar angle		7.8 ± 1.1	8.2 ± 1.1	0.07941	-0.3
Lateral tarsal angle		155.3 ± 3.8	154.4 ± 4.2	0.18982	0.9
Lateral-medial area index (LAMAI)		0,08 ± 0,07	0.09 ± 0.06	0.41264	-0.01
Lateral-medial force index		0.96 ± 0.31	1.08 ± 0.33	0.02692	-0.12
Lateral-medial force-time integral index		-5,0 ± 26,5	2.8 ± 30.7	0.09416	-7.9
Long plantar angle (g)		15.7 ± 2.3	16.3 ± 2.1	0.07941	-0.6
Long plantar angle (p)		15.7 ± 2.3	16.3 ± 2.1	0.07941	-0.6
Maximum force	big toe	56.2 ± 27.7	55.3 ± 32.5	0.85492	0.9
Maximum force	hindfoot	231.9 ± 88.7	215.8 ± 84.4	0.25566	16.1
Maximum force	Lateral forefoot	134.0 ± 60.7	149.0 ± 58.8	0.13228	-15
Maximum force	Lateral hindfoot	108.5 ± 49.5	101.9 ± 42.8	0.38932	6.6
Maximum force	Lateral midfoot	41.7 ± 37.3	61.5 ± 45.3	0.00461	-19.8
Maximum force	Medial forefoot	65.9 ± 35.0	57.6 ± 36.4	0.1632	8.3
Maximum force	Medial hindfoot	128.1 ± 47.6	119.0 ± 48.9	0.26042	9.1
Maximum force	Medial midfoot	6.4 ± 6.3	6.5 ± 7.4	0.94244	-0.1
Maximum force	MH1	62.4 ± 33.1	55.0 ± 30.5	0.15741	7.4
Maximum force	MH2	68.3 ± 32.3	71.5 ± 30.9	0.53619	-3.2
Maximum force	MH3	73.7 ± 30.0	78.9 ± 30.0	0.28751	-5.2
Maximum force	MH4	50.0 ± 19.3	52.7 ± 17.7	0.36239	-2.8
Maximum force	MH5	23.7 ± 15.5	25.0 ± 12.6	0.59133	-1.2
Maximum force	midfoot	46.8 ± 38.2	65.5 ± 46.6	0.00816	-18.6
Maximum force	Toes 2345	27.5 ± 16.9	29.4 ± 15.9	0.48407	-1.9
Maximum force	Total object	333.3 ± 101.7	334.0 ± 105.7	0.96724	-0.7
Maximum force (normalized to BW)	big toe	19.7 ± 10.0	18.7 ± 10.1	0.53867	1
Maximum force (normalized to BW)	hindfoot	76.5 ± 13.5	71.8 ± 16.0	0.05267	4.7
Maximum force (normalized to BW)	Lateral forefoot	44.6 ± 13.7	50.1 ± 15.2	0.02152	-5.6
Maximum force (normalized to BW)	Lateral hindfoot	35.0 ± 8.1	33.3 ± 9.2	0.23987	1.7
Maximum force (normalized to BW)	Lateral midfoot	12.9 ± 9.3	19.3 ± 10.9	0.0002	-6.4
Maximum force (normalized to BW)	Medial forefoot	21.6 ± 8.9	18.4 ± 9.7	0.04339	3.1
Maximum force (normalized to BW)	Medial hindfoot	42.6 ± 9.7	38.9 ± 9.7	0.02446	3.7
Maximum force (normalized to BW)	Medial midfoot	2.2 ± 2.3	2.1 ± 2.0	0.75531	0.1
Maximum force (normalized to BW)	MH1	20.5 ± 8.7	18.3 ± 9.2	0.13482	2.2
Maximum force (normalized to BW)	MH2	22.0 ± 6.1	23.3 ± 4.5	0.14708	-1.3
Maximum force (normalized to BW)	MH3	24.5 ± 5.8	26.5 ± 5.4	0.03034	-2
Maximum force (normalized to BW)	MH4	17.1 ± 5.4	18.3 ± 5.7	0.18987	-1.2
Maximum force (normalized to BW)	MH5	7.9 ± 4.6	8.8 ± 4.6	0.2785	-0.8
Maximum force (normalized to BW)	midfoot	14.8 ± 9.4	20.9 ± 10.9	0.0003	-6.2
Maximum force (normalized to BW)	Toes 2345	9.4 ± 4.6	10.0 ± 4.8	0.47137	-0.6
Maximum force (normalized to BW)	Total object	112.1 ± 8.1	112.0 ± 8.1	0.95026	0.1
Maximum mean pressure	big toe	57.2 ± 32.7	50.1 ± 32.3	0.18148	7.1
Maximum mean pressure	hindfoot	76.2 ± 25.8	63.5 ± 26.7	0.00347	12.7
Maximum mean pressure	Lateral forefoot	76.5 ± 27.3	88.5 ± 30.9	0.01462	-12

Maximum mean pressure	Lateral hindfoot	68.2 ± 25.2	58.1 ± 24.8	0.01713	10
Maximum mean pressure	Lateral midfoot	22.1 ± 11.7	25.1 ± 11.7	0.13167	-2.9
Maximum mean pressure	Medial forefoot	55.2 ± 22.2	50.5 ± 23.9	0.22017	4.7
Maximum mean pressure	Medial hindfoot	76.1 ± 25.9	64.2 ± 27.0	0.00741	11.9
Maximum mean pressure	Medial midfoot	14.8 ± 10.0	13.5 ± 11.0	0.47339	1.3
Maximum mean pressure	MH1	54.6 ± 21.9	53.1 ± 23.5	0.68007	1.5
Maximum mean pressure	MH2	73.9 ± 27.9	81.2 ± 26.3	0.10312	-7.3
Maximum mean pressure	MH3	75.6 ± 26.8	85.9 ± 28.5	0.02434	-10.3
Maximum mean pressure	MH4	57.3 ± 20.8	61.9 ± 21.8	0.1879	-4.6
Maximum mean pressure	MH5	43.9 ± 26.6	51.0 ± 30.2	0.12688	-7.1
Maximum mean pressure	midfoot	23.4 ± 11.9	26.1 ± 11.5	0.16502	-2.7
Maximum mean pressure	Toes 2345	24.5 ± 11.2	29.1 ± 11.6	0.01431	-4.6
Maximum mean pressure	Total object	101.0 ± 23.8	105.0 ± 24.3	0.30995	-4
Maximum velocity		1.39 ± 1.19	1.20 ± 0.74	0.24899	0.19
Mean pressure	big toe	75.7 ± 29.3	72.8 ± 32.1	0.56346	2.9
Mean pressure	hindfoot	115.7 ± 33.2	107.2 ± 32.2	0.11572	8.5
Mean pressure	Lateral forefoot	79.8 ± 22.2	88.0 ± 23.3	0.03227	-8.2
Mean pressure	Lateral hindfoot	105.2 ± 33.7	100.1 ± 31.1	0.34938	5.1
Mean pressure	Lateral midfoot	33.1 ± 13.7	41.2 ± 17.1	0.00211	-8.1
Mean pressure	Medial forefoot	72.4 ± 26.0	62.7 ± 24.7	0.02201	9.7
Mean pressure	Medial hindfoot	127.2 ± 36.5	115.8 ± 35.2	0.05884	11.3
Mean pressure	Medial midfoot	30.3 ± 9.9	30.0 ± 10.9	0.87625	0.3
Mean pressure	MH1	72.9 ± 26.3	64.2 ± 23.9	0.03582	8.7
Mean pressure	MH2	98.1 ± 33.3	100.6 ± 28.8	0.63704	-2.4
Mean pressure	MH3	97.0 ± 25.9	101.9 ± 24.8	0.23703	-4.9
Mean pressure	MH4	75.5 ± 22.2	83.4 ± 24.9	0.0415	-7.9
Mean pressure	MH5	59.6 ± 26.5	67.0 ± 28.6	0.10413	-7.4
Mean pressure	midfoot	33.5 ± 12.3	39.9 ± 15.4	0.00499	-6.5
Mean pressure	Toes 2345	36.6 ± 10.8	39.9 ± 13.0	0.09807	-3.3
Mean pressure	Total object	80.2 ± 15.2	78.9 ± 13.4	0.56965	1.3
Mean pressure for MVP	big toe	28.8 ± 13.2	25.9 ± 12.5	0.16293	2.9
Mean pressure for MVP	hindfoot	41.8 ± 13.2	35.9 ± 13.2	0.00732	5.9
Mean pressure for MVP	Lateral forefoot	35.9 ± 10.6	39.7 ± 11.1	0.03834	-3.8
Mean pressure for MVP	Lateral hindfoot	38.8 ± 13.6	33.8 ± 12.8	0.02309	5
Mean pressure for MVP	Lateral midfoot	14.2 ± 5.8	15.7 ± 5.2	0.09904	-1.5
Mean pressure for MVP	Medial forefoot	33.3 ± 10.8	30.2 ± 12.1	0.09725	3.2
Mean pressure for MVP	Medial hindfoot	44.9 ± 13.6	38.9 ± 14.1	0.00969	6
Mean pressure for MVP	Medial midfoot	12.2 ± 7.2	10.7 ± 7.7	0.23725	1.5
Mean pressure for MVP	MH1	33.3 ± 10.8	30.9 ± 11.2	0.17383	2.5
Mean pressure for MVP	MH2	44.4 ± 15.4	48.5 ± 15.1	0.10561	-4
Mean pressure for MVP	MH3	44.3 ± 13.3	46.8 ± 12.9	0.24385	-2.5

Mean pressure for MVP	MH4	33.6 ± 11.1	37.2 ± 11.9	0.05649	-3.6
Mean pressure for MVP	MH5	26.0 ± 11.6	29.4 ± 13.0	0.09389	-3.4
Mean pressure for MVP	midfoot	14.5 ± 5.7	15.8 ± 5.0	0.15962	-1.2
Mean pressure for MVP	Toes 2345	15.0 ± 4.7	16.5 ± 4.7	0.04456	-1.6
Mean pressure for MVP	Total object	35.6 ± 5.3	34.2 ± 4.6	0.10733	1.3
Mean velocity		0.31 ± 0.05	0.29 ± 0.05	0.06572	0.02
Medial contact area		40.01 ± 8.25	40.99 ± 8.54	0.47591	- 0.98
Medial force-time integral		83.4 ± 30.6	82.8 ± 32.3	0.89962	0.6
Medial plantar angle		7.8 ± 1.1	8.2 ± 1.1	0.07941	-0.3
Medial tarsal angle		146.3 ± 3.8	146.4 ± 2.8	0.91831	-0.1
Peak mean pressure	big toe	77.9 ± 29.4	76.4 ± 33.4	0.77379	1.5
Peak mean pressure	hindfoot	116.1 ± 32.0	107.0 ± 30.7	0.07858	9.1
Peak mean pressure	Lateral forefoot	82.7 ± 21.0	89.4 ± 23.4	0.07081	-6.7
Peak mean pressure	Lateral hindfoot	107.4 ± 33.4	100.9 ± 30.2	0.22669	6.4
Peak mean pressure	Lateral midfoot	36.0 ± 11.8	40.9 ± 16.5	0.04015	-4.9
Peak mean pressure	Medial forefoot	75.9 ± 27.5	67.3 ± 26.1	0.05763	8.5
Peak mean pressure	Medial hindfoot	127.4 ± 34.6	116.3 ± 33.5	0.05184	11.1
Peak mean pressure	Medial midfoot	35.2 ± 11.3	35.3 ± 13.5	0.95256	-0.1
Peak mean pressure	MH1	76.3 ± 27.7	68.8 ± 25.5	0.08589	7.5
Peak mean pressure	MH2	107.1 ± 37.4	111.4 ± 31.9	0.44651	-4.3
Peak mean pressure	MH3	108.3 ± 31.0	112.9 ± 31.7	0.36887	-4.6
Peak mean pressure	MH4	75.0 ± 20.5	81.9 ± 24.2	0.06195	-6.9
Peak mean pressure	MH5	61.6 ± 27.4	69.3 ± 29.7	0.10435	-7.6
Peak mean pressure	midfoot	36.2 ± 11.3	40.3 ± 15.6	0.06392	-4.2
Peak mean pressure	Toes 2345	38.6 ± 11.1	42.2 ± 13.6	0.08116	-3.6
Peak mean pressure	Total object	92.8 ± 26.5	90.9 ± 23.0	0.63714	1.9
Peak pressure	big toe	171.5 ± 77.4	164.3 ± 91.1	0.60273	7.2
Peak pressure	hindfoot	229.7 ± 72.2	204.4 ± 64.6	0.02501	25.3
Peak pressure	Lateral forefoot	187.2 ± 66.6	212.3 ± 75.4	0.03532	- 25.1
Peak pressure	Lateral hindfoot	202.1 ± 63.0	185.8 ± 61.0	0.11435	16.4
Peak pressure	Lateral midfoot	66.6 ± 26.9	79.4 ± 35.7	0.01542	- 12.9
Peak pressure	Medial forefoot	131.3 ± 54.0	115.3 ± 49.5	0.06581	16
Peak pressure	Medial hindfoot	229.9 ± 72.4	205.0 ± 65.7	0.03204	24.9
Peak pressure	Medial midfoot	51.2 ± 24.7	51.0 ± 27.3	0.96482	0.2
Peak pressure	MH1	131.7 ± 57.5	122.0 ± 52.6	0.28447	9.7
Peak pressure	MH2	176.3 ± 63.0	186.5 ± 56.8	0.29935	- 10.2
Peak pressure	MH3	179.3 ± 56.2	196.0 ± 62.8	0.08746	- 16.7
Peak pressure	MH4	134.8 ± 44.1	148.5 ± 56.9	0.10209	- 13.7
Peak pressure	MH5	114.3 ± 72.0	132.9 ± 76.8	0.12933	- 18.5
Peak pressure	midfoot	70.3 ± 28.0	82.1 ± 35.2	0.02541	- 11.7
Peak pressure	Toes 2345	87.2 ± 33.3	101.3 ± 40.3	0.02111	-

					14.1
Peak pressure	Total object	260.8 ± 66.7	268.5 ± 66.1	0.4805	-7.7
Posterior plantar angle		29.1 ± 2.4	29.5 ± 2.3	0.32721	-0.4
Pressure-time integral	big toe	41.3 ± 23.6	37.9 ± 24.6	0.39568	3.3
Pressure-time integral	hindfoot	53.2 ± 18.1	46.2 ± 19.8	0.02623	7
Pressure-time integral	Lateral forefoot	56.1 ± 22.5	67.2 ± 22.4	0.00347	- 11.1
Pressure-time integral	Lateral hindfoot	47.8 ± 17.6	42.7 ± 18.6	0.09407	5.1
Pressure-time integral	Lateral midfoot	18.7 ± 10.5	22.5 ± 11.1	0.03948	-3.7
Pressure-time integral	Medial forefoot	39.1 ± 16.0	37.0 ± 17.6	0.4541	2.1
Pressure-time integral	Medial hindfoot	53.2 ± 18.0	46.8 ± 19.8	0.0436	6.4
Pressure-time integral	Medial midfoot	10.9 ± 6.6	10.4 ± 6.7	0.65958	0.5
Pressure-time integral	MH1	38.3 ± 15.9	38.7 ± 17.4	0.88821	-0.4
Pressure-time integral	MH2	51.1 ± 19.6	58.7 ± 18.9	0.01652	-7.6
Pressure-time integral	MH3	52.6 ± 18.9	62.1 ± 19.9	0.00318	-9.5
Pressure-time integral	MH4	41.1 ± 16.5	47.8 ± 19.5	0.02548	-6.7
Pressure-time integral	MH5	31.1 ± 20.4	36.7 ± 20.9	0.09909	-5.6
Pressure-time integral	midfoot	19.6 ± 10.5	23.0 ± 10.8	0.05162	-3.4
Pressure-time integral	Toes 2345	18.4 ± 8.9	22.5 ± 10.2	0.01085	-4
Pressure-time integral	Total object	108.0 ± 24.7	111.9 ± 22.8	0.31659	-3.9
Subarch angle		102.5 ± 9.2	105.0 ± 9.0	0.13327	-2.4
Transverse plantar angle		24.9 ± 11.3	22.1 ± 12.4	0.13996	2.9
|Ar-Al|		6.56 ± 5.38	5.34 ± 4.03	0.11756	1.22