

Radiographic evaluation of the congruency of the first metatarsophalangeal joint in hallux valgus

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Research article

Keywords: Hallux valgus, Metatarsophalangeal joint, Congruency, Metatarsophalangeal joint angle, Congruency index

Posted Date: September 2nd, 2021

DOI: <https://doi.org/10.21203/rs.3.rs-847258/v1>

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Abstract

Background

The congruency of the first metatarsophalangeal (MTP) joint was extremely important for the selection of operating methods and prognosis, while its radiographic evaluation method was relatively lacking. The purpose of this article was to explore the radiographic indicators for evaluating the congruency of the first MTP joint.

Methods

The patients who had X-ray of weightbearing in the outpatient system were selected, excluding patients with trauma, deformity, and history of operation. 183 patients with 245 feet were included. The hallux valgus angle (HVA), distal metatarsal articular angle (DMAA), metatarsophalangeal joint angle (MTPJA), congruency index (CI) and tibial sesamoid position (TSP) were measured and do statistical analysis.

Results

The higher the degree of hallux valgus, the higher the proportion of incongruency of the first MTP joint. Significant differences were found in DMAA, MTPJA and CI between the congruency and incongruency groups of patients with moderate to severe hallux valgus ($P < 0.05$). The area under curve (AUC) of the receiver operating characteristic(ROC) curve for MTPJA and CI was 0.906 and 0.884, the sensitivity and specificity reached 0.791 and 0.862, 0.949 and 0.644, and the critical values were 10.67 and 0.765 respectively. The correlation test indicated that in the congruency group, DMAA and HVA had positive correlation, but MTPJA, CI and HVA had low correlation coefficients. DMAA and HVA were not correlated in the incongruency group, while MTPJA and HVA were significantly positively correlated, and CI and HVA showed a negative correlation ($P < 0.05$).

Conclusion

MTPJA and CI are indicators that can quantitatively evaluate the congruency of the first MTP joint, taking 10° and 0.765 as the demarcation points respectively. Clinically, the congruency of MTP joint should be considered when choosing operating methods for different degrees of hallux valgus, MTPJA and CI can be used as quantitative evaluation indicators.

Background

The congruency the first MTP joint is all-important for the choice of hallux valgus operation and the postoperative recurrence^[1]. The data on the congruency of the MTP joint are quite different^[2, 3]. Patients with moderate to severe hallux valgus, who have a high degree of congruency and incongruency of the MTP joint. For patients with hallux valgus of the same degree, there are big differences in the choice of operating methods due to the existence of MTP joint congruency and incongruency. Double metatarsal osteotomy (DMO) was often required for the patients who had large HVA and congruency of the MTP joint^[4, 5]. It has been reported in the literature that the congruency of the first MTP joint is calculated with the help of two lines referring to the base of the proximal phalanx and the

estimated cartilage surface of the first metatarsal head, while there was no quantitative measurement index for the congruency of first MTP joint^[8].

The purpose of this article was to quantitatively evaluate the congruency of MTP joint through two innovative indicators, and to conduct diagnostic experimental analysis, aiming to evaluate the evaluation value of the two new indicators and the intrinsic relationship between different MTP joint radiographic indicators. It also provides a basis for the selection of operating options for patients with different types of hallux valgus and the prevention of postoperative recurrence.

Methods

Patients with hallux valgus who had X-ray of weightbearing in the outpatient system from January 2018 to January 2021 were selected. Patients with ankle trauma, fractures, and a history of previous operations, or younger than 18 years old were excluded. Finally, 183 cases of hallux valgus patients with 245 feet were included, including 51 males and 132 females. According to the classification criteria for hallux valgus, 131 feet (53.47%) of patients with mild hallux valgus (HVA: 15–30°), 80 feet (32.65%) of patients with moderate hallux valgus (HVA: 31–40°), 34 feet (13.88%) of patients with severe hallux valgus (HVA ≥ 40°).

The HVA, DMAA, TSP were measured in weightbearing foot anterior-posterior images refer to the measurement method of the previous literature (Fig. 1A, B, E).^[6] According to the congruency and incongruency of first MTP joint in patients with hallux valgus were exist, we innovatively designed two new measurement indicators, naming MTPJA (metatarsophalangeal joint angle) and CI (Congruency index), which was defined by MTPJA as: on the weightbearing foot anterior-posterior images, draw a straight line with the inner and outer edges articular surface of the proximal phalanx and the distal metatarsal respectively, and the angle between the two straight lines was MTPJA (Fig. 1C). CI was as described in our previous article^[7]. The ratio of the curve length of the metatarsophalangeal joint contact surface to the curve length of the metatarsal head cartilage surface was defined as CI, aiming to measure the congruency of MTP joint (Fig. 1D). There were currently no quantitative indicators to assess whether the metatarsophalangeal joint was congruency. And it was only based on the physician's subjective feeling to observe whether the articular surfaces at both ends of the metatarsophalangeal joint are parallel (Fig. 1F). Based on this, we selected two doctors with 20 years of experience in foot and ankle surgery divided the 245 feet into the congruency and incongruency group. The HVA, DMAA, MTPJA, CI and TSP were statistically analyzed between hallux valgus of different degrees and between congruency and incongruency group. Diagnostic tests were performed for MTPJA and CI, and ROC curves were plotted. Area under curve (AUC), sensitivity, specificity and critical value were calculated.

The SPSS 20.0 software was used for statistical analysis. Quantitative data were expressed as $X \pm S$. The comparison of different parameters between congruency and incongruency group of patients with hallux valgus of different degrees was performed by independent sample Student t test. The diagnostic test of MTPJA and CI used ROC curve drawing, and calculates its AUC, critical value, sensitivity, specificity and other parameters. Correlation test was carried out between different parameters of congruency and incongruency group and calculate the correlation coefficient. The difference was statistically significant with $P < 0.05$.

Results

HVA, DMAA, MTPJA and TSP increased significantly following the degree of hallux valgus aggravated, while CI decreased ($P < 0.05$) (Table.1). Based on the previous observation of the parallelism of the first metatarsophalangeal joint surface as the gold standard^[8], 245 feet were divided into the congruency and incongruency group. In total, about 2/3 (64.49%) of the patients' first MTP joint were congruency, and about 1/3 (35.51%) of the patients' first MTP joint were incongruency. The majority of patients with mild hallux valgus are congruency, while the severe were incongruency. Patients with moderate hallux valgus were basically the same ($P < 0.05$) (Fig. 2).

Although the difference in HVA between the two groups of patients with mild and moderate hallux valgus was statistically significant, the numerical differences were not significant. Patients with severe hallux valgus did not have a significant difference in HVA between the two groups. In the congruency group, the TSP of patients with mild to moderate hallux valgus was lower than that of the incongruency group, while there was no significant difference between the two groups of patients with severe hallux valgus. In terms of DMAA, the mild patients had no significant difference, but for moderate to severe hallux valgus, the DMAA of the congruency group was greater than that of the incongruency group. Among all patients, the MTPJA of the congruency group was lower than that of the incongruency group, and the CI was greater than that of the incongruency group (Table 2).

Table 1
Comparison and analysis of different indexes in patients with different degrees of hallux valgus.

Index	Mild hallux valgus	P*	Moderate hallux valgus	P**	Severe hallux valgus	P***
Sex (M/F)	37/70	0.060	15/55	0.637	5/24	0.073
Age (year)	45.60 ± 16.55	0.064	51.44 ± 17.33	0.116	57.34 ± 17.21	0.003
L/R	69/62	0.981	42/38	0.807	17/17	0.781
HVA(°)	24.07 ± 4.01	0.000	33.72 ± 2.79	0.000	46.52 ± 4.71	0.000
DMAA(°)	12.55 ± 5.78	0.000	18.98 ± 7.26	0.040	22.01 ± 10.75	0.000
MTPJA(°)	8.25 ± 4.88	0.000	12.91 ± 7.45	0.000	23.42 ± 13.90	0.000
CI	0.85 ± 0.07	0.000	0.80 ± 0.09	0.000	0.65 ± 0.16	0.000
TSP	3.87 ± 1.65	0.000	5.15 ± 1.67	0.004	6.09 ± 1.08	0.000
Feet number (ratio)	131(53.47%)	0.003	80(32.65%)	0.000	34(13.88%)	0.000
Congruency/Incongruency	112/19	0.000	38/42	0.017	8/26	0.000
Abbreviations:						
HVA, Hallux valgus angle; DMAA, Distal metatarsal articular angle; MTPJA, The first metatarsophalangeal joint angle; CI, Congruency index; TSP, Tibial sesamoid position						
P*: Comparisons between mild and moderate hallux valgus. P**[]Comparisons between moderate and severe hallux valgus. P***[]Comparisons between mild and severe hallux valgus						

Table 2

Comparison and analysis of different index of patients with different degrees of hallux valgus between congruency and incongruency groups

Groups	Index	Congruency	Incongruency	T value	P value
Mild	HVA(°)	23.60 ± 4.00	26.78 ± 2.88	-4.172	0.000
	MTPJA(°)	7.41 ± 3.99	13.23 ± 6.58	-3.744	0.001
	DMAA(°)	11.27 ± 5.69	14.20 ± 6.22	-1.350	0.179
	CI	0.86 ± 0.06	0.78 ± 0.07	5.071	0.000
	TSP	3.55 ± 1.55	5.74 ± 0.81	-9.265	0.000
Moderate	HVA(°)	32.98 ± 2.54	34.39 ± 2.86	-2.329	0.022
	MTPJA(°)	7.57 ± 4.72	17.73 ± 6.05	-8.309	0.000
	DMAA(°)	22.04 ± 7.77	16.22 ± 5.54	3.888	0.000
	CI	0.85 ± 0.06	0.75 ± 0.08	6.932	0.000
	TSP	4.37 ± 1.85	5.86 ± 1.09	-4.320	0.000
Severe	HVA(°)	43.98 ± 1.89	47.30 ± 5.06	-1.803	0.081
	MTPJA(°)	4.90 ± 3.32	29.12 ± 10.42	-6.415	0.000
	DMAA(°)	32.45 ± 5.04	18.79 ± 10.00	5.154	0.000
	CI	0.80 ± 0.05	0.61 ± 0.15	5.925	0.000
	TSP	5.50 ± 1.41	6.27 ± 0.92	-1.447	0.182

Abbreviations: HVA, Hallux valgus angle; DMAA, Distal metatarsal articular angle; MTPJA, The first metatarsophalangeal joint angle; CI, Congruency index; TSP, Tibial sesamoid position

Because of the significant difference in MTPJA and CI between the two groups of patients with hallux valgus of different degrees ($P < 0.001$), we performed diagnostic tests and plot the ROC curve with the data of MTPJA and CI. The AUC of MTPJA and CI were 0.906 and 0.884 respectively, which were both greater than 0.7 ($P < 0.001$), showing have significant diagnostic value (Fig. 3[4]). The sensitivity and specificity of MTPJA reached 0.791 and 0.862 respectively, and the sensitivity and specificity of CI also reached 0.949 and 0.644. In addition, the critical value of MTPJA was 10.67, and the critical value of CI was 0.765 (Table 3).

Table 3

Diagnostic test between two new index and congruency of the metatarsophalangeal joint

Index	Critical value	Sensitivity	Specificity	AUC	P value	Youden index	PPV	NPV	+LR	-LR
MTPJA	10.670	0.791	0.862	0.906	0.000	0.653	0.912	0.694	5.736	0.242
CI	0.765	0.949	0.644	0.884	0.000	0.593	0.829	0.875	2.664	0.079

Abbreviations: MTPJA, The first metatarsophalangeal joint angle; CI, Congruency index; AUC, Area under the Curve; PPV, Positive Predictive Value; NPV, Negative predictive value; +LR, Positive likelihood ratio; -LR, Negative likelihood ratio

Correlation tests were performed on 5 parameters of two groups of patients. In the congruency group, DMAA was positively correlated with HVA, while the correlation coefficients between MTPJA, CI and HVA were low. In the incongruency group, DMAA was not correlated with HVA, while MTPJA was positively correlated with HVA, and CI was negatively correlated with HVA. MTPJA and CI were negatively correlated regardless of whether it was a congruency group or an incongruency group (Table 4&5).

Table 4
Correlation test of different index in the congruency group

Index	MTPJA	DMAA	CI	TSP
HVA	0.103(0.197)	0.691(0.000)	-0.272(0.001)	0.345(0.000)
MTPJA	-	-0.377(0.000)	-0.538(0.000)	0.036(0.654)
DMAA	-	-	0.057(0.475)	0.517(0.000)
CI	-	-	-	-0.392(0.000)
Abbreviations: HVA, Hallux valgus angle; DMAA, Distal metatarsal articular angle; MTPJA, The first metatarsophalangeal joint angle; CI, Congruency index; TSP, Tibial sesamoid position				

Table 5
Correlation test of different index in the incongruency group

Index	MTPJA	DMAA	CI	TSP
HVA	0.554(0.000)	0.212(0.048)	-0.546(0.000)	0.331(0.002)
MTPJA	-	-0.468(0.000)	-0.760(0.000)	0.389(0.000)
DMAA	-	-	0.322(0.002)	-0.101(0.350)
CI	-	-	-	-0.557(0.000)
Abbreviations: HVA, Hallux valgus angle; DMAA, Distal metatarsal articular angle; MTPJA, The first metatarsophalangeal joint angle; CI, Congruency index; TSP, Tibial sesamoid position				

Discussion

The congruency of the first MTP joint play important role in the selection of operating method postoperative recurrence in hallux valgus. Studies have shown that the incongruency of the postoperative MTP joint was highly correlated with the recurrence of hallux valgus^[8]. Previous literature reported^[8], the evaluation of the congruency of the first MTP joint was only judged by the doctor's visually assessing whether the arcs of the MTP joint articular surface were parallel, however there was no quantitative indicator. In addition, DMAA was also often used to assess the dislocation of the first MTP joint^[9]. For example, for patients with severe hallux valgus accompanied by increased DMAA, Double metatarsal osteotomy (DMO) was a quite effective operating method^[10]. But in fact, due to its own complications such as shortening the length of the first metatarsal bone, postoperative avascular necrosis of the metatarsal head, and metastatic metatarsalgia, the application of this technique was limited to a certain extent^[11]. Wang's article compares the efficacy of rotating scarf osteotomy and DMO for hallux valgus accompanied by increased DMAA. It was believed that there was no significant difference between the two methods, but the former had a lower incidence of complications^[11]. Jeong used the point-connecting method for

measuring HVA and IMA, also due to consideration of the MTP joints' congruency and incongruency, which would affect the assessment of the severity of hallux valgus^[12].

Facts have proved that DMAA is not suitable for evaluating the congruency of the first MTP joint^[13]. For the larger metatarsals of DMAA, there will also be two situations where the MTP joints are congruency and incongruency. The statistical results showed that there was an obvious relationship between the patients' DMAA and the congruency of the first MTP joint for moderate to severe hallux valgus. The DMAA of the congruency group was significantly greater than that of the incongruency group, indicating that the application of DMAA alone to assess whether the first MTP joint was congruency or not was not reliable. We had innovatively proposed two quantitative evaluation indexes for the congruency of the first MTP joint on the weightbearing foot anterior-posterior images, MTPJA and CI, which were quantitatively measured by measuring the angles of the articular surfaces at both ends and the degree of mating of the articular surfaces (Fig. 1). Because of our data were not clinically needed patients and lots of asymptomatic patients were also included, resulting in a larger proportion of patients with mild hallux valgus, most of which were congruency MTP joint. While the proportions of congruency and incongruency patients with moderate hallux valgus can be basically the same. For patients with severe hallux valgus, nearly a quarter of them were congruency with the first MTP joint, which ratio is similar to the data reported by Coughlin^[14]. In addition, as the severity of hallux valgus gradually increased, MTPJA gradually increased, and CI gradually decreased, indicating that the contact surface of the first MTP joint surface will gradually decrease.

Compared the difference between congruency and incongruency groups, there was no difference in HVA between the two groups in patients with mild, moderate or severe hallux valgus. But in patients with moderate to severe hallux valgus, the difference between MTPJA and CI was large, the CI of the congruency group was greater than that of the incongruency group, while the MTPJA was smaller than that of the incongruency group, indicating that MTPJA and CI could effectively assess the congruency of the first MTP joint. By drawing ROC curves for MTPJA and CI, the AUC was 0.906 and 0.884 respectively, and both had diagnostic power. The critical value of MTPJA was 10.67 and CI was 0.765. We can define that if the value of MTPJA is greater than 10° or CI is less than 0.765, the first MTP joint is considered as congruency, and the degree of congruency can be measured by the specific value of the two. That is the larger the MTPJA and the smaller the CI, the greater the degree of congruency. In our previous article^[7], 36 patients (38 feet) with moderate to severe hallux valgus were followed up at different times before and after surgery, and their CI recovered from 0.75 before surgery to 0.95 at the last follow-up. Same as HVA, IMA, etc., all of the indicators have been well recovered, which also verifies the effectiveness of this indicator to a certain extent.

In terms of correlation test, DMAA and HVA had a positive correlation in the congruency group, while there was no correlation between the two in the incongruency group. Indicating that if DMAA was used to assess the degree of hallux valgus, it is only limited to the congruency group. In patients with significant dislocation of the first MTP joint, DMAA is less effective in assessing the severity of hallux valgus. Therefore, for more severe hallux valgus surgery, DMAA still needs to be measured in the congruency group, and the value of DMAA will be used to determine whether to perform DMO. In the congruency group, the correlation coefficients between MTPJA, CI and HVA were low, while in the incongruency group, MTPJA and HVA were significantly positively correlated, and CI and HVA were negatively correlated, that is, the more severe the hallux valgus, the more deviated MTPJA and CI normal range. Of course, because the smaller the value of MTPJA and the larger the value of CI, it indicates that the matching relationship of hallux valgus is better. Therefore, whether it is a congruency group or an incongruency group, there is a significant negative correlation between the two.

The present paper also has some limitations that should be taken into consideration. First of all, this study only focuses on the statistical analysis of radiological parameters, and does not apply MTPJA and CI to the comparison of parameters before and after the operation in hallux valgus patients. This is what we need to include in the next step of our research. In addition, the patients included in this study have a certain deviation. The patients with mild hallux valgus are too large, but due to the metatarsophalangeal joint mismatch mostly occurs in patients with moderate to severe hallux valgus, we believe that the data in the study is still reliable.

In summary, different degrees of hallux valgus, especially in patients with moderate to severe hallux valgus, have the first MTP joint of congruency and incongruency. DMAA has poor performance in evaluating matching relationships. The previous imaging indicators are only qualitative evaluations. MTPJA and CI can be quantitative to evaluate the congruency of the first MTP joint, 10° and 0.765 are used as the demarcation points respectively. Clinically, it is necessary to consider the congruency of the first MTP joint in the selection of different degrees of hallux valgus surgery. MTPJA and CI can be used as quantitative evaluation indicators.

Ethics approval

This study was approved by the Ethics Committee, and the part number was: (B) KY2021052.

Declarations

Ethics approval

This study was approved by the Ethics Committee, and the part number was: (B) KY2021052.

Consent for publication

Not applicable.

Availability of data and materials

The datasets used during the current study are available from the corresponding author on reasonable request.

Conflicts of interest

None of the authors have any conflicts of interest to declare.

Funding

Leading Scientific and Technological Innovation Talents Under the National "Ten Thousand People Plan" (4139Z2B1).

Authors' contributions

Yan Li was in charge of manuscript writing, clinical data collection and data statistics; Xu Tao and Kanglai Tang were in charge of the overall design and acceptance.

Acknowledgments

Not applicable.

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Figures



Figure 1

The imaging indicators of the first MTP joint on the weightbearing foot anterior-posterior images. A: Hallux valgus angle, HVA; B: Distal metatarsal articular angle, DMAA; C: Metatarsophalangeal joint angle, MTPJA; D: Congruency index, CI; E: Tibial sesamoid position, TSP; F: The evaluating of the congruency of the first MTP joint.

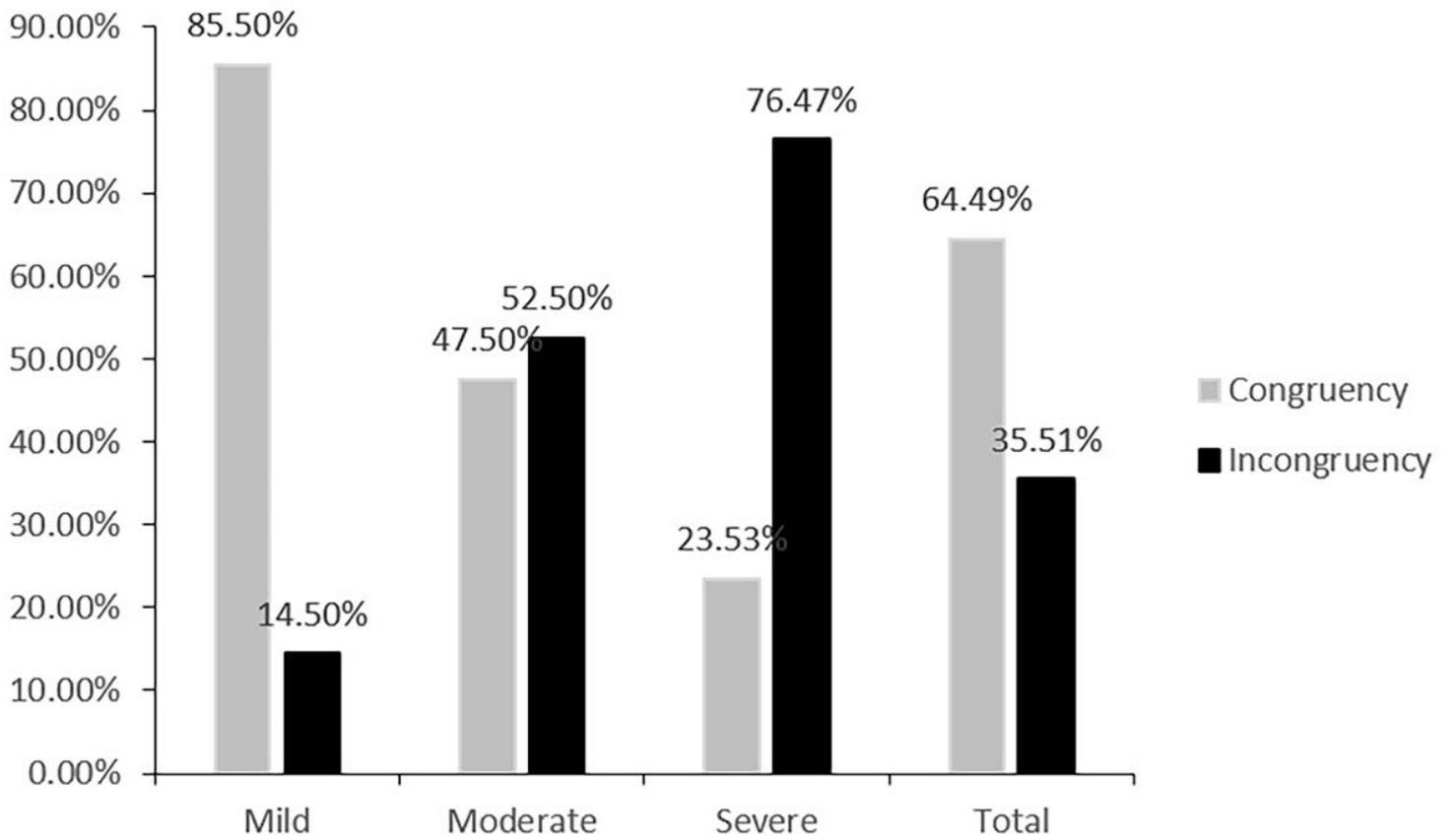


Figure 2

The distribution of the congruency of first metatarsophalangeal joint in patients with mild to severe hallux valgus

ROC curve

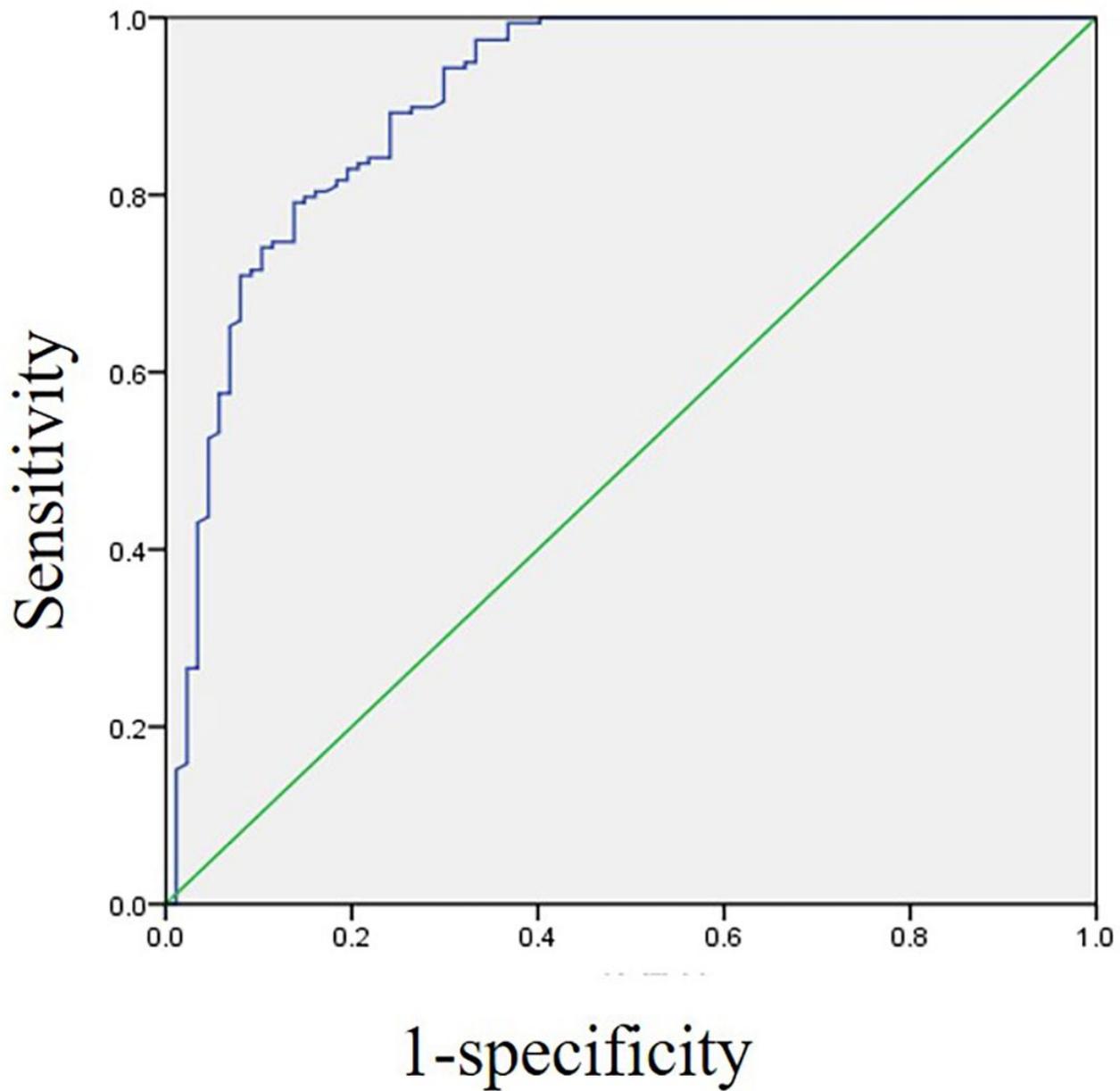


Figure 3

The ROC curve of metatarsophalangeal joint angle (MTPJA) and congruency of the first metatarsophalangeal (MTP) joint, the area under the curve (AUC) was 0.906.

ROC curve

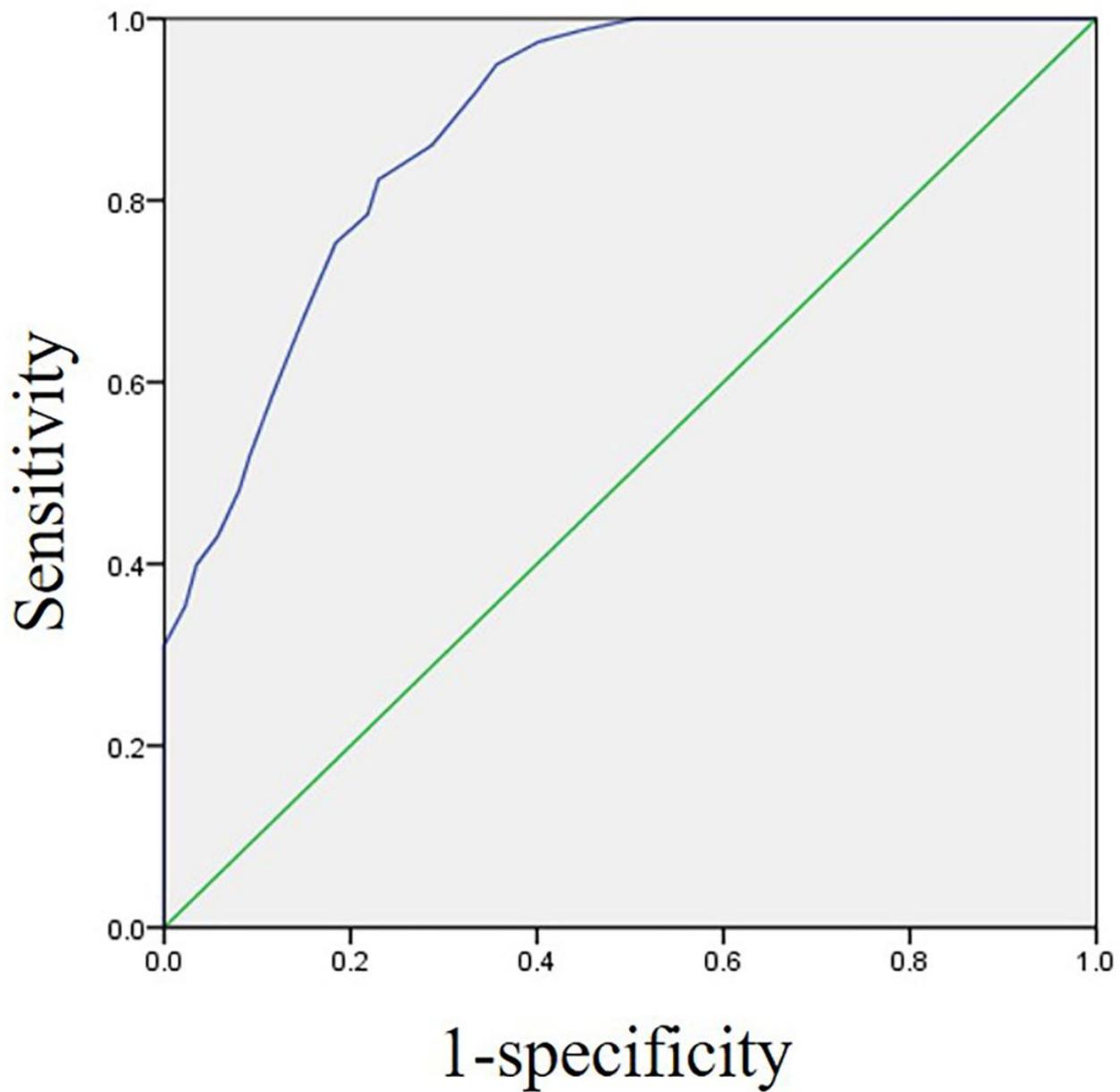


Figure 4

The ROC curve of congruency index (CI) and congruency of the first metatarsophalangeal (MTP) joint. the area under the curve (AUC) was 0.884.