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Original Article *Özgün Araştırma*

THE MRI FINDINGS IN PATIENTS WITH IDIOPATHIC CARPAL TUNNEL SYNDROME BEFORE AND AFTER TREATMENT

İdiyopatik Karpal Tünel Sendromlu Hastalarda Tedavi Öncesi ve Sonrası MRG Bulguları

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ABSTRACT

Objective: In this study, while evaluating the effectiveness of splint, injection, paraffin and surgical treatment with Magnetic Resonance Imaging (MRI) in patients with idiopathic carpal tunnel syndrome (CTS), we investigated the consistency between MRI measurements performed by different observers.

Material and Methods: Boston questionnaires were evaluated, and the cross-sectional areas (CSA) of the median nerve were measured by two different observers, in 50 hands of 50 patients with idiopathic CTS.

Results: The CSA of the median nerve at the radiocarpal joint level of the canal were significantly larger than the values at the hamate level of the canal when values before treatment and three months after treatment were compared (p<0.001; <0.001 respectively). Measurements of the CSA of the median nerve, taken by the first observer, were found to be significantly lower in the post-treatment period at both the radiocarpal joint and hamate level, compared with the pre-treatment period (p<0.001; 0.002 respectively). Measurements of CSA of the median nerve at the radiocarpal joint and hamate level performed by the observers in the pre- and post-treatment periods, were found to be highly compatible with one another.

Conclusion: MRI is a valuable investigative technique for use with CTS patients, for the diagnosis of idiopathic CTS. When evaluating the efficacy of treatment, measurements of CSA of the median nerve are important, particularly at the proximal regions of the canal. The compatibility between the MRI measurements of the different observers, led us to consider that the measurements were objective.

***Keywords**: Carpal tunnel syndrome, magnetic resonance imaging, cross-sectional area, wrist*

ÖZ

Amaç: İdiyopatik Karpal Tünel Sendromu (KTS) tanılı hastalarda splint, enjeksiyon, parafin ve cerrahi tedavinin etkinliğini Manyetik Rezonans Görüntüleme (MRG) ile değerlendirirken, farklı gözlemciler tarafından yapılan MRG ölçümleri arasındaki tutarlılığı araştırdık.

Gereç ve Yöntemler: İdiyopatik KTS tanılı 50 hastanın 50 eli Boston anketi ile değerlendirildi ve 2 farklı gözlemci tarafından MRG'de median sinir kesitsel alanı ölçüldü.

Bulgular: Tedavi öncesi ve tedaviden 3 ay sonra radiokarpal eklem düzeyi, hamat kemik düzeyine göre istatistiksel anlamlı olarak daha yüksekti (Sırasıyla p<0.001; <0.001). 1. gözlemci tarafından yapılan gerek radiokarpal eklem düzey gerek hamat kemik düzeyinde yapılan median sinir kesitsel alan ölçümünde tedavi öncesine göre tedavi sonrasında istatistiksel olarak anlamlı azalma gözlendi (Sırasıyla p<0.001; 0.002). Gözlemcilerin tedavi öncesi ve sonrası yapmış olduğu radiokarpal eklem düzey, hamat kemik düzey ölçümlerinin önemli derecede uyumlu olduğu görüldü.

Sonuç: KTS'de idyopatik KTS tanısı koyarken MRG kıymetli bir tetkiktir. Tedavinin etkinliğini değerlendirirken özellikle kanal proksimalinden yapılan median sinir kesitsel alan ölçümleri değerlidir. Farklı gözlemciler arasındaki uyumluluk ölçümlerin objektif olduğunu düşündürmektedir.

***Anahtar Kelimeler**: Karpal tünel sendromu, manyetik rezonans görüntüleme, sinir kesitsel alanı, el bileği*

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INTRODUCTION

Carpal Tunnel Syndrome (CTS) is caused by increased pressure within the carpal tunnel that results in mechanical compression and local ischemia-mediated damage to the median nerve (1,2). Its classic symptoms include the sensations of numbness, tingling and burning, or pain in the first three fingers and the lateral side of the fourth finger (3). CTS is the most frequently existing entrapment neuropathy in the upper extremities and it accounts for 90%of entrapment neuropathies (4,5). It exists in 3.8%of the general population, and its annual incidence is 276:100000 (5-7). In females its prevalence is 9.2%and in males 6%, showing a higher prevalence in females (8).

For treatment, conservative methods may be preferred in mild and moderate CTS cases, and surgical methods in moderate and severe cases (9). Conservative treatment methods include splinting, corticosteroid injections, systemic steroid therapy, non-steroid anti-inflammatory drugs, vitamin B6, diuretics, manual therapy, exercise, paraffin, acupuncture, massage therapy, ultrasound, low-intensity laser therapy and phonophoresis (1,9-13). CTS is diagnosed by clinical symptoms, and physical examination (14). It is possible to confirm diagnosis, and to determine the degree of compression by electromyography (EMG) (3).

To our knowledge, imaging techniques are not used routinely in the diagnosis of CTS; however following diagnosis, these methods may be required for a differential diagnosis of idiopathic CTS. In this context, conventional X-Ray, computerized tomography, ultrasonography (USG), and magnetic resonance imaging (MRI) may be administered (9). In many studies, imaging techniques have not been used in the diagnosis of idiopathic CTS. However, we consider that the utilization of methods like USG and MRI are essential, in order to exclude the existence of an occupying lesion in the carpal tunnel.

In the present study, our objective was to reveal the changes in MRI, during evaluation of the therapeutic efficacies of splinting, injection, paraffin, and surgical approach, which had been used to treat idiopathic CTS. We also investigated the compatibility between the MRI measurements performed by different observers.

MATERIALS AND METHODS

After obtaining local ethical committee approval (Date: 18.09.2015, Desicion number: 20/10) the study was retrospectively designed. This study included 50 hands of 50 patients with unilateral idiopathic CTS (36 females, 14 males; ranged between 27-81 years of age) who attended a Physical Therapy and Rehabilitation Hospital between April 2013 and July 2014, and to whom splinting, injection, paraffin or surgery were applied for treatment. Patients with secondary CTS, cervical radiculopathy, and polyneuropathy were not included in the study. Before treatment nerve conduction studies, MRI of the wrist and Boston Carpal Tunnel Questionnaire were evaluated. Three months after the treatment MRI of the wrist and Boston Carpal Tunnel Questionnaire were once more evaluated.

Nerve Conduction Studies

The patients were separated into groups of mild, moderate and severe stages, depending on the results of electromyographic investigation (15). The group with mild CTS included only patients with slow speeds of sensory conduction (<42 m/s between the first finger and wrist, and <44 m/s between the third finger and wrist). The group with moderate CTS included cases with slowing speeds of sensory conduction, associated with an increased distal motor delay of the median nerve (>4.0 ms) while the severe group included cases in whom sensory conduction had failed to be recorded, and distal motor delay of the median nerve was found to increase (>4.0 ms) or motor conduction had also failed to be recorded (15).

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MRI Protocol

MRIs of the wrist were conducted in the pretreatment period and three months following therapy in the patients with CTS diagnosed by clinical signs and EMG, in order to evaluate the median nerve cross-sectional area (CSA). All patients underwent MRI in the prone position, with hands placed anteriorly. The MRI investigations were performed using a 1.5 Tesla GE MR Signa, EXCITE HDx MRI device, using 4-channel extremity coils. In all patients, the images were obtained using coronal T2 oil-printed, coronal T1 spin-echo, axial T1 spin-echo, axial proton density oil-print, and sagittal T2 fast spin-echo sequences. The parameters of MRI were as follows: section thickness 3 mm, FOV 14x7 cm, and matrix 256x192. TR and TE were determined to be 700 ms and 16 ms, respectively in the T1-weighted images (T1WI), and 4700 ms and 85.3 ms, respectively in the T2-weighted images (T2WI). The measurements were taken by two independent radiologists, using images obtained at the workstation. A single measurement was made for each level. The measurements were made on the T1WI. In our study, the margins of the median nerve were visualized more clearly on the T1WI, and therefore T1WIs were used for all measurements. At the workstation, the T1WI obtained in the axial plane was placed on one screen, and the image obtained in the coronal plane was placed on the other; the two screens were synchronized at the level at which the measurement would be made was marked on the image in coronal plane, and the same corresponding level in the axial plane was used for measurement in this plane. The level of radiocarpal joint was considered as the entrance level, and the plane of the hook of the hamate bone was considered as the reference for the exit level (Figures 1 and 2). The CSA measurements were made using manual tracing. The area values were expressed as 'square millimeters-mm^2'.

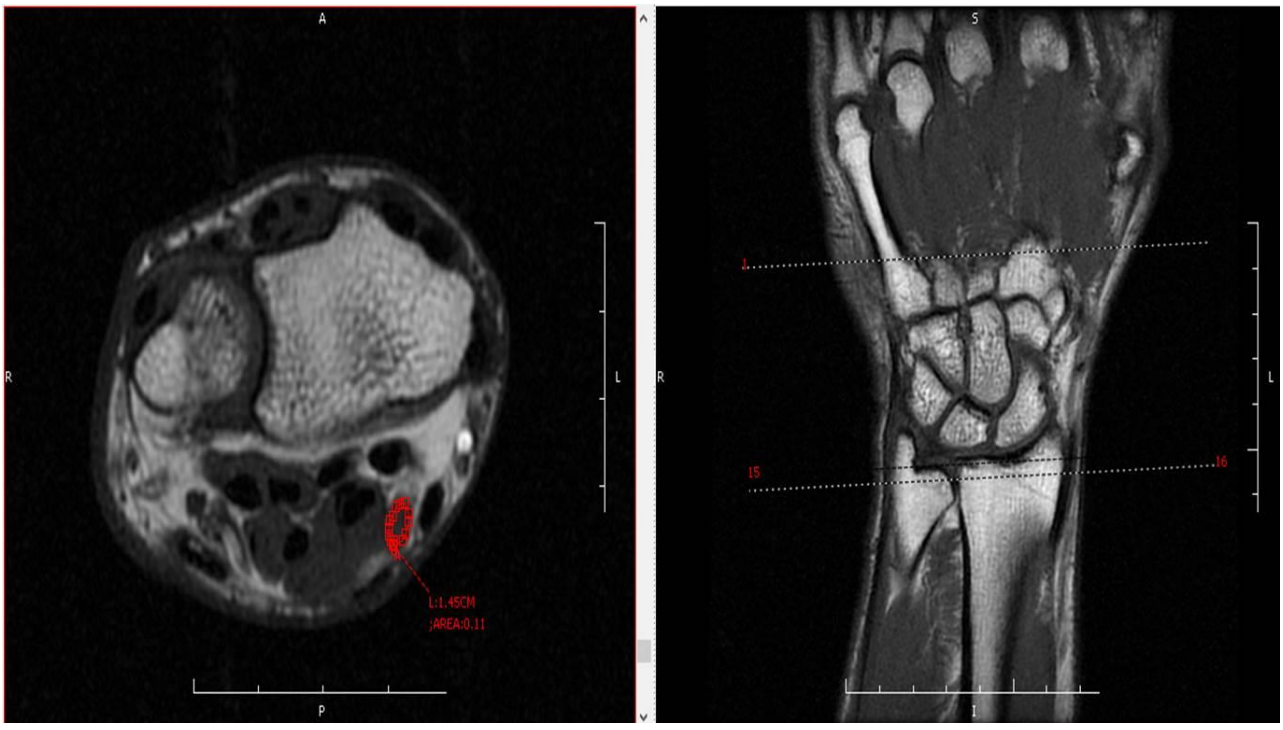

Figure 1: T1A.S. Coronal and axial section, entrance of the canal.

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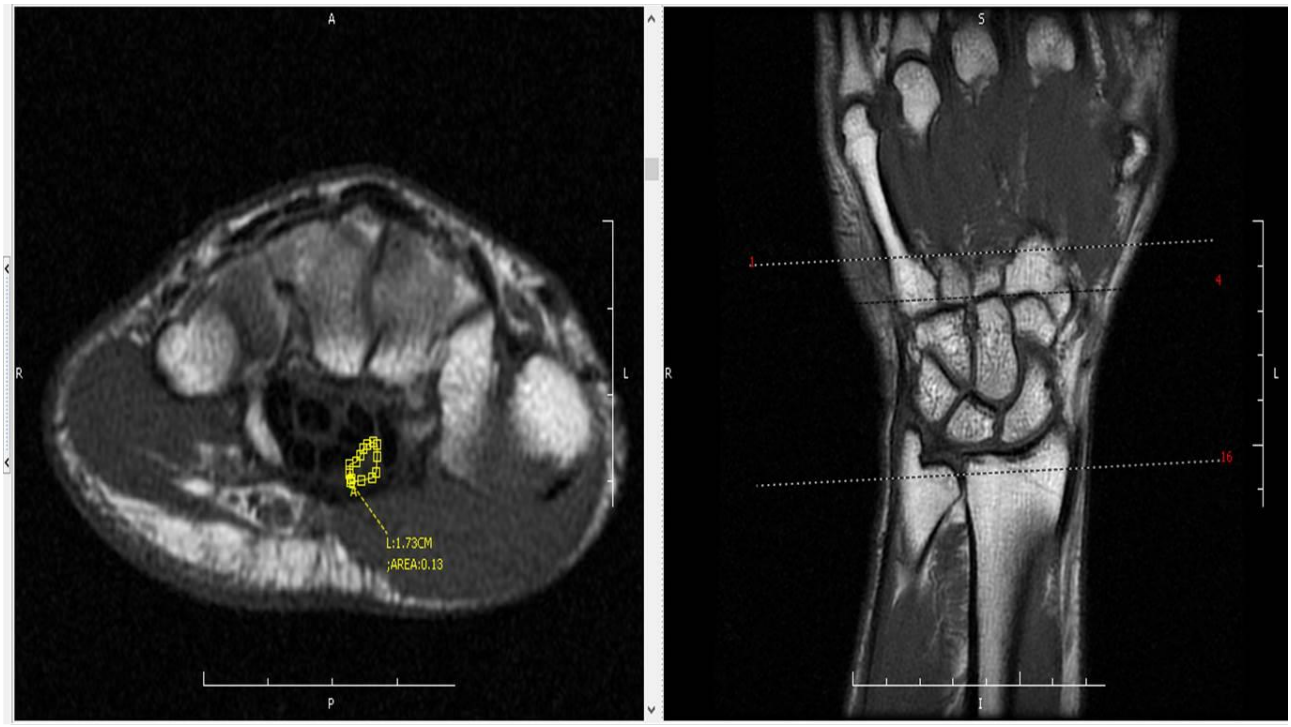

Figure 2: T1A.S. Coronal and axial section, exit of the canal.

P*araffin Treatment*

The patients underwent paraffin therapy with the dip-and-wrap method in the hospital, one session a day for 10 days. The paraffin bath temperature was 55 °C. The symptomatic hand was dipped five times into the paraffin wax and wrapped for 20 minutes (13,16).

Use of Splint

In this study, patients used the rest splint at night, for three months. This splint leaves the fingers free and maintains the wrist in neutral position.

Injection Treatment

The injection technique is applied as previously recommended in some studies, and a mixture of 0.5 ml of 20 mg methylprednisolone and 0.5 ml of 0.5 cc 2%20 mg prilocaine was administered via injection into the medial of the palmaris longus tendon (17,18).

Surgery

The 'standard open carpal tunnel release' is applied as the surgical method. This kind of surgery consists of a longitudinal incision at the base of the hand, and in line with this incision, the incisions of the subcutaneous tissue, the superficial palmar fascia, and the muscle of the palmaris brevis (19).

Clinical Assessment

During the pretreatment period, and at the control evaluation three months after therapy, the patients were evaluated by the Boston Carpal Tunnel Questionnaire, the validity and reliability studies of which have also been made in the Turkish language (20,21). It has two scales, which are the Symptom Severity Scale (BQSS) and the Functional Status Scale (BQFSS), with each scale generating a final score ranging from 1 (no disability) to 5 (most disability) (20).

Statistical Analysis

Data were analyzed using the SPSS for Windows 11.5 software. The Shapiro Wilk test was used to evaluate whether the continuous numerical variables were distributed normally. In the expression of descriptive statistical data, the mean ± standard deviation or median (minimum-maximum) were used for the continuous numerical variables, and the number of cases and percent values (%) were used for the nominal variables.

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The Wilcoxon Sign test was used to determine if the post-treatment median values of the BQSS, BQFSS, and the median values at the entrance and exit regions of the canal differed significantly, compared with the pretreatment values. The Spearman's correlation test was used to determine if statistically significant correlations existed between the continuous variables. The significance of compatibility between the clinical measurements performed by two different observers were evaluated by calculating the intraclass correlation coefficient, and 95%confidence interval. A p value <0.05 was accepted to be statistically significant, unless indicated otherwise. However in order to control a possible Type I error, Bonferroni correction was applied in all multiple comparisons.

RESULTS

In the present study, we evaluated the data of 50 hands of 50 patients. The patients' demographic features, hand dominancy, side of complaint, duration of complaint, EMG signs and treatment modalities are presented in Table 1.

In the 3-month evaluation, the median value of the BQSS and BQFSS scores were found to decrease significantly, compared with the baseline values (p<0.001; <0.001 respectively) (Table 2).

The measurements of the median nerve CSA at the radiocarpal level that was made by the first observer were found to have decreased significantly in the 3-month measurement, compared with the baseline value (p<0.001). The measurement at the hamate level was also found to have decreased significantly in the 3-month measurement, compared with the baseline value (p=0.002). The baseline and 3-month value of median nerve CSA at the radiocarpal level were significantly higher, compared with the value at the hamate level (p<0.001; <0.001 respectively) (Table 3).

Table 1: Demographic and clinical characteristics of the cases.

Variables	n=50
Age (year)	51.9±13.2 (mean s.d.)
Age interval (year)	27-81
Gender	
Male	14 (28.0%)
Female	36 (72.0%)
Dominant hand	
Right	44 (88.0%)
Left	6 (12.0%)
Side of complaint	
Right	27 (54.0%)
Left	23 (46.0%)
Duration of complaint (month)	12 (1-120) (median s.d.)
EMG	
Mild	23 (46.0%)
Moderate	21 (42.0%)
Severe	6 (12.0%)
Treatment	
Surgery	14 (28.0%)
Injection	20 (40.0%)
Paraffin	10 (20.0%)
Splint	6 (12.0%)

The measurement of the median nerve CSA at the radiocarpal level that was made by the second observer did not differ significantly in the 3-month measurement, compared with the baseline value (p=0.102). The measurement at the hamate level did not differ significantly in the 3-month measurement, compared with the baseline value (p=0.974). The baseline and 3-month value of median nerve CSA at the radiocarpal level was significantly higher, compared with the value at the hamate level (p<0.001; <0.001 respectively) (Table 3).

The baseline measurements of the median nerve CSA made by the two observers at the radiocarpal level, were found to be highly compatible with one another (ICC=0.671; 95%confidence interval: 0.485–0.799 and p<0.001). The baseline measurements made by the two observers at the hamate level, were found to be highly compatible with one another (ICC=0.681;

95%confidence interval: 0.499–0.806 and p<0.001) (Table 4).

The 3-month measurements of the median nerve CSA made by the two observers at the radiocarpal level, were found to be frequently compatible with one another (ICC=0.534; 95%confidence interval: 0.303–0.706 and p<0.001). The 3-month measurements made by the observers at the hamate level were found to be highly compatible with one another (ICC=0.480; 95%confidence interval: 0.235–0.667 and p<0.001) (Table 4).

Statistically significant correlations did not exist between the baseline measurements made by the first observer at the radiocarpal and hamate level, and the baseline values of the BQSS and BQFSS, according to Bonferroni correction (p>0.00625). Statistically significant correlations did not exist between the 3-month measurements made by the first observer at the radiocarpal and hamate level, and the 3-month values of the BQSS and BQFSS, according to Bonferroni correction (p>0.00625) (Table 5).

No statistically significant correlations existed between the baseline measurements made by the second observer at the radiocarpal and hamate level, and the baseline values of the BQSS and BQFSS, according to Bonferroni correction (p>0.00625). No statistically significant correlations existed between the 3-month measurements made by the second observer at the radiocarpal and hamate levels, and the 3-month values of the BQSS and BQFSS, according to Bonferroni correction (p>0.00625) (Table 5).

As determined by the Bonferroni correction, statistically significant correlations did not exist between the changes in 3-month measurements relative to the baseline values determined by the first observer at the radiocarpal and hamate levels, and the changes in 3-month values of BQSS and BQFSS relative to their pretreatment values (p>0.0125) (Table 6).

As determined by the Bonferroni correction, statistically significant correlations did not exist between the changes in 3-month measurements relative to the baseline values determined by the second observer at the radiocarpal and hamate levels, and the changes in 3-month values of BQSS and BQFSS relative to their baseline values (p>0.0125) (Table 6).

Table 2: Changes in BQSS and BQFSS Scores (n=50)

	Baseline	3 mo	p-value †	Change
BQSS	2.8 (1.3-4.1)	1.8 (1.0-3.4)	<0,001	-0.4 (-3.1-0.3)
BQFSS	2.2 (1.3-4.9)	1.9 (1.0-4.0)	<0,001	-0.3 (-3.8- 0.5)

Data represent mean (S.D.)

†Wilcoxon Sign test

Abbreviations: BQSS, Boston Questionnaire Symptom Severity Scale. BQFSS, Boston Questionnaire Functional Status Scale

Table 3: Changes in the median nerve CSA (mm^2)

	Baseline	3 mo	p-value †	Change
1st observer				
Radiocarpal level	1.0 (1.0-2.0)	0.9 (0.6-1.4)	<0,001	-0,1 (-0.6 – 0.4)
Hamate level	0.9 (0.5-1.2)	0.8 (0.4-1.2)	0.002	0.0 (-0.2 - 0.1)
p value ‡	<0,001	<0,001		
2nd observer				
Radiocarpal level	11 (06-17)	09 (06-16)	0102	00 (-06 - 03)
Hamate level	08 (06-14)	0.9 (0.5-1.2)	0974	00 (-03 - 02)
p value ‡	<0,001	<0,001		

Data represent mean (S.D.)
† The results of comparisons between the baseline and 3 month were accepted to be significant statistically for the p values <0.0125, according to the Wilcoxon Sign test, Bonferroni correction;
‡ The results of comparisons between the measurements made at the radiocarpal and hamate level, were accepted to be significant statistically for the p values <0.0125, according to the Wilcoxon Sign test, Bonferroni correction.
Abbreviation: CSA, cross sectional area

Table 4: The reliability levels of the baseline and 3 month median nerve CSA measurements made by the two observers.

	ICC	95% Confidence Interval	p-value †
Pretreatment			
Radiocarpal level	0.671	0.485-0.799	<0.001
Hamate level	0.681	0.499-0.806	<0.001
Post-treatment			
Radiocarpal level	0.534	0.303-0.706	<0.001
Hamate level	0.480	0.235-0.667	<0.001

† Results were accepted to be statistically significant for p values <0.0125, according to Bonferroni correction.
Abbreviation: ICC, Intra-class correlation coefficient. CSA, cross sectional area.

Table 5: The coefficients of correlations and significance levels existing between the pretreatment and post-treatment scores of the BQSS and BQFSS, and the measurements at the entrance and exit regions of the canal.

	BQSS		**BQFSS**	
	Coefficient of correlation	p-value †	Coefficient of correlation	p-value †
1st observer				
Baseline				
Radiocarpal level	-0.271	0.057	-0.354	0.012
Hamate level	-0.052	0.719	0.001	0.992
3 month				
Radiocarpal level	0.038	0.795	0.035	0.809
Hamate level	-0.144	0.318	0.062	0.671
2nd observer				
Baseline				
Radiocarpal level	0.071	0.624	-0.215	0.133
Hamate level	-0.035	0.810	-0.138	0.341
3 month				
Radiocarpal level	-0.198	0.168	-0.164	0.255
Hamate level	-0.076	0.599	-0.191	0.183

†The results were accepted to be statistically significant for p values <0.00625, according to the Spearman's correlation test, Bonferroni correction.
Abbreviations: BQSS, Boston Questionnaire Symptom Severity Scale. BQFSS, Boston Questionnaire Functional Status Scale

Table 6: The coefficients of correlations and significance levels existing between the changes in post-treatment scores of the BQSS and BQFSS relative to their baseline levels, and the changes in the measurements at the radiocarpal and hamate level.

	BQSS		**BQFSS**	
	Coefficient of correlation	p-value †	Coefficient of correlation	p-value †
1st observer				
Radiocarpal level	0.238	0.095	0.029	0.840
Hamate level	-0.296	0.037	-0.345	0.014
2nd observer				
Radiocarpal level	0.132	0.362	-0.093	0.521
Hamate level	0.232	0.104	-0.102	0.479

†As determined by the Spearman's correlation test, Bonferroni correction; the results were accepted to be statistically significant for p values <0.0125.

Abbreviations: BQSS, Boston Questionnaire Symptom Severity Scale. BQFSS, Boston Questionnaire Functional Status Scale.

DISCUSSION

At the outset, we should say that treatments by splinting, paraffin, injection, and surgical approach are mostly effective on the severity and function of the symptoms. Although our patient group was not homogeneous, appropriate treatment for the appropriate cases, results in effective treatment (22).

In the evaluation of the efficacy of treatment in CTS, many indicators of the severity of the clinical symptoms, functional evaluations, signs of physical examination, and questionnaires are available; however, there are limited number of studies about the morphological changes following treatment. Imaging techniques, such as computed tomography and X-Ray, can only indicate bony stenosis, fractures, and calcification of the soft tissue. However, MR imaging can be useful in revealing the causes of nerve compression or elongation. MRI studies carried out on CTS have provided an insight into the pathophysiology of idiopathic CTS. Proximal enlargement of the CSA of the median nerve in the carpal tunnel, greater signal intensity over the median nerve (MN) and palmar bowing of the transverse carpal ligament (TCL), are the typical indicators of idiopathic CTS (23). Other potential indicators of CTS on MRI include increases in CSA area, flattening of the MN and peritendon pathology (24). Nevertheless, it is still MRI that provides the greatest diagnostic sensitivity for idiopathic CTS (25).

There are a limited number of studies in the literature evaluating the efficacy of treatment for CTS by taking measurements using MRI (26-28). In the study of Aoki et al., the efficacy of steroid injections was evaluated using MRI, by the median nerve T2 signal, and flattening ratio, and a statistically significant improvement was established. Schmid et al. evaluated the efficacy of splinting and exercise using MRI, by the signal intensity of the median nerve, and the measurement of the palmar bowing of the carpal tunnel; they determined a statistically significant improvement of the median nerve signal intensity only at the proximal region of the canal (26-28).

In our study, as determined by the measurements of both observers, the median nerve CSA at the radiocarpal level was found to be significantly larger in the pre- and post-treatment periods, compared with the

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median nerve CSA at the hamate level. Enlargement at the proximal level has previously been demonstrated in some studies, and the results of our study support these findings (23, 29).

Contradictory to our results, Momose et al. conducted a study including patients who underwent endoscopic tunnel release, and the median nerve CSA at the level of the hamate bone, was found to be larger following surgery, compared with the value ascertained before surgery (27). The median nerve CSA at the level of the pisiform bone did not differ significantly between the pre- and post-treatment measurements. However, this study included only patients who underwent endoscopic carpal tunnel release. Our study included the patients who underwent open surgery, and the participation of other treatment groups in the study makes the patient group more heterogeneous. Further studies are necessary to separately evaluate each treatment method.

The measurements of the two observers were found to be compatible with one another, and this finding leads us to consider that the measurements taken at the radiocarpal level may be more reliable in evaluating the efficacy of treatment.

Statistically significant correlations did not exist between the pre- and post-treatment measurements conducted by the first and second observers at the radiocarpal and hamate levels, and the pre- and post-treatment values of the BQSS and BQFSS. Moreover, changes in the post-treatment measurements performed by the first and second observers at the radiocarpal joint and hamate levels, did not correlate significantly with the changes in post-treatment values of the BQSS and BQFSS, relative to their pretreatment levels. We could not find a study in the literature that evaluates the correlations between CSA measurements on MRI, and the symptom severity and function. This subject also requires further investigations.

In conclusion, MRI is a valuable investigative technique for use with CTS patients, for the diagnosis of idiopathic CTS but it is expensive and may not be feasible for daily routine. Measurements of the median nerve CSA, specifically those made at the proximal region of the canal, are important in evaluating the efficacy of treatment. The compatibility between the different observers has led us to consider that the measurements are objective. Further studies are needed on this subject.

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