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Research Article

Fixed Point Theorems for T-Contractions with c-Distance on Cone Metric Spaces

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Abstract. In this paper, we prove the existence and uniqueness of the fixed point for T-contraction mapping under the concept of c-Distance in cone metric spaces with solid cone. The obtained results extend and generalize well known comparable results in the literature.

Keywords. Cone metric space; Fixed point; T-contraction

MSC. 47H09; 47H10

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1. Introduction

In 2007, Huang and Zhang [14] introduced the concept of Cone metric spaces, they replaced set of real numbers by an ordered Banach space and proved some fixed point theorems for contractive type conditions in cone metric spaces. Then, many authors studied the existence and uniqueness of the fixed point in cone metric spaces, see for example [1, 2, 15]. In 2009, Beiranvand *et al.* [3] introduced the new classes of contractive function and established the Banach principle. Since then, fixed point theorems for T-contraction mapping on cone metric spaces have been appeared, see for instance [5–7, 11, 13, 16].

Recently, Cho *et al.* [4], and Wang and Guo [18] defined the concept of the c-Distance in a cone metric space. Later, several fixed and common fixed point results on cone metric spaces with c-Distance were introduced in [8–10, 12, 13, 17] and references were mentioned therein.

The aim of this paper is to improve certain results proved in a recent paper of Rahimi *et al.* [16], Filipovic *et al.* [11], Dubey *et al.* [9], and Fadail *et al.* [13].

2. Preliminaries

Definition 2.1 ([14]). Let E be a real Banach space and θ denote to the zero element in E. A cone P is the subset of E such that

(i) P is closed, non empty and $P \neq \{\theta\}$;

(ii) $a, b \in \mathbb{R}$, $a, b \geq 0$; $x, y \in P \Longrightarrow ax + by \in P$;

(iii) $x \in P$ and $-x \in P \Longrightarrow x = \theta$.

Given a Cone $P \subseteq E$, we define a partial ordering $\preccurlyeq$ with respect to P by $x \preccurlyeq y$ if and only if $y - x \in P$. We write $x \prec y$ to indicate that $x \preccurlyeq y$ but $x \neq y$, while $x \ll y$ will stand for $y - x \in \operatorname{int} P$, $\operatorname{int} P$ denotes the interior of P.

Definition 2.2 ([14]). The cone P is called normal if there is a number $K > 0$ such that for all $x, y \in E$, $\theta \preccurlyeq x \preccurlyeq y$ implies $\|x\| \leq K\|y\|$. The least positive number satisfying above is called the normal constant of P.

In the following we always suppose E is a Banach Space, P is a cone in E with $\operatorname{int} P \neq \phi$ and $\preccurlyeq$ is partial ordering with respect to P.

Definition 2.3 ([14]). Let X be a nonempty set. Suppose the mapping $d : X \times X \to E$ satisfies:

(i) If $\theta \preccurlyeq d(x, y)$ for all $x, y \in X$ and $d(x, y) = \theta$ if and only if $x = y$;

(ii) $d(x, y) = d(y, x)$ for all $x, y \in X$;

(iii) $d(x, y) \preccurlyeq d(x, z) + d(y, z)$ for all $x, y, z \in X$.

Then d is called a cone metric on X and (X, d) is called a cone metric space.

Example 2.4 ([14]). Let $E = \mathbb{R}^2$, $P = \{(x, y) \in E : x, y \geq 0\} \subseteq \mathbb{R}^2$, $X = \mathbb{R}$ and $d : X \times X \to E$ is such that $d(x, y) = (|x - y|, \alpha|x - y|)$, where $\alpha \geq 0$ is a constant. Then (X, d) is a cone metric space.

Definition 2.5 ([14]). Let (X, d) be a cone metric space, let $\{x_n\}$ be a sequence in X and $x \in X$.

(1) For all $c \in E$ with $\theta \ll c$, if there exists a positive integer N such that $d(x_n, x) \ll c$ for all $n > N$, then $\{x_n\}$ is said to be convergent and $\{x_n\}$ converges to x.

(2) For all $c \in E$ with $\theta \ll c$, if there exists a positive integer N such that for all $n, m > N$, $d(x_n, x_m) \ll c$, then $\{x_n\}$ is called a Cauchy sequence in X.

(3) If every Cauchy sequence in X is convergent in X then (X,d) is called a complete cone metric space.

Lemma 2.6 ([15]). (1) *If E be a real Banach space with a cone P and $a \preccurlyeq \lambda a$ where $a \in P$ and $0 \le \lambda < 1$, then $a = \theta$.*

(2) *If $c \in \operatorname{int} P$, $\theta \preccurlyeq a_n$ and $a_n \to \theta$, then there exists a positive integer N such that $a_n \ll c$ for all $n \ge N$.*

Next, we give the notion of c- Distance on a cone metric space (X,d) of Cho *et al.* in [4].

Definition 2.7 ([4]). Let (X,d) be a cone metric space. A function $q : X \times X \to E$ is called a c-Distance on X if the following conditions hold:

(q_1) $\theta \preccurlyeq q(x,y)$ for all $x,y \in X$;

(q_2) $q(x,z) \preccurlyeq q(x,y) + q(y,z)$ for all $x,y,z \in X$;

(q_3) for each $x \in X$ and $n \ge 1$ if $q(x,y_n) \preccurlyeq u$ for some $u = u_x \in P$, then $q(x,y) \preccurlyeq u$ whenever $\{y_n\}$ is a sequence in X converging to a point $y \in X$;

(q_4) for all $c \in E$ with $\theta \ll c$, there exists $e \in E$ with $\theta \ll e$ such that $q(z,x) \ll e$ and $q(z,y) \ll e$ imply $d(x,y) \ll c$.

Example 2.8 ([4]). Let $E = \mathbb{R}$ and $P = \{x \in E : x \ge 0\}$, $X = [0,\infty)$ and define a mapping $d : X \times X \to E$ is defined by $d(x,y) = |x - y|$ for all $x,y \in X$. Then (X,d) be a cone metric space. Define a mapping $q : X \times X \to E$ by $q(x,y) = y$ for all $x,y \in X$. Then q is a c-Distance on X.

Lemma 2.9 ([4]). *Let (X,d) be a cone metric space and q be a c-Distance on X. Let $\{x_n\}$ and $\{y_n\}$ be a sequences in X and $x,y,z \in X$. Suppose that $\{u_n\}$ is a sequence in P converging to θ. Then the following hold:*

(1) *If $q(x_n,y) \preccurlyeq u_n$ and $q(x_n,z) \preccurlyeq u_n$ then $y = z$.*

(2) *If $q(x_n,y_n) \preccurlyeq u_n$ and $q(x_n,z) \preccurlyeq u_n$, then $\{y_n\}$ converges to z.*

(3) *If $q(x_n,x_m) \preccurlyeq u_n$ for $m > n$, then $\{x_n\}$ is Cauchy sequence in X.*

(4) *If $q(y,x_n) \preccurlyeq u_n$, then $\{x_n\}$ is Cauchy sequence in X.*

Remark 2.10 ([4]). (1) $q(x,y) = q(y,x)$ does not necessarily for all $x,y \in X$.

(2) If $q(x,y) = \theta$ is not necessarily equivalent to $x = y$ for all $x,y \in X$.

Definition 2.11 ([3]). Let (X,d) be a cone metric space, P a solid cone and $T : X \to X$. Then

(a) T is said to be continuous if $x_n = x^*$ implies that $Tx_n = Tx^*$ for all $\{x_n\}$ in X;

(b) T is said to be sequentially convergent if we have, for every sequence $\{x_n\}$, if $\{Tx_n\}$ is convergent, then $\{x_n\}$ is also convergent;

(c) T is said to be subsequentially convergent if we have, for every sequence $\{x_n\}$ that $\{Tx_n\}$ is convergent implies $\{x_n\}$ has a convergent subsequence.

3. Main Results

Theorem 3.1. *Let (X,d) be a complete cone metric space, P a solid cone and q be a c-Distance on X. In addition let $T : X \to X$ is a continuous and one to one mapping and $f : X \to X$ be a map satisfying the contractive condition,*

$$q(Tfx,Tfy) \preccurlyeq k(x,y)q(Tx,Ty)+l(x,y)q(Tx,Tfx)+r(x,y)q(Ty,Tfy) + t(x,y)[q(Tx,Tfy)+q(Ty,Tfx)] \tag{1}$$

for all $x, y \in X$, where k, l, r and t are nonnegative functions satisfying

$$\sup_{x,y\in X}\{k(x,y)+l(x,y)+r(x,y)+2t(x,y)\} \le \lambda < 1 \tag{2}$$

that is, f is a T-contraction. Then

(1) *For each $x_0 \in X$, $\{Tf^n x_0\}$ is a Cauchy sequence.*
(Define the iterate sequence $\{x_n\}$ by $x_{n+1} = f^{n+1}\, x_0$.)

(2) *There exists a $Z_{x_0} \in X$ such that $\lim_{n\to\infty} Tf^n x_0 = Z_{x_0}$.*

(3) *If T is subsequentially convergent, then $\{f^n x_0\}$ has a convergent subsequence.*

(4) *There exists a unique $\omega_{x_0} \in X$ such that $f\omega_{x_0} = \omega_{x_0}$ that is, f has a unique fixed point.*

(5) *If T is sequentially convergent, then, for each $x_0 \in X$, the sequence $\{f^n x_0\}$ converges to ω_{x_0}.*

Proof. Choose $x_0 \in X$, set $x_1 = fx_0$, $x_2 = fx_1 = f^2x_0 = \cdot = x_{n+1} = fx_n = f^{n+1}x_0$. Then, we have

$$\begin{aligned} q(Tx_n,Tx_{n+1}) &= q(Tfx_{n-1},Tfx_n) \\ &\preccurlyeq k(x_{n-1},x_n)q(Tx_{n-1},Tx_n)+l(x_{n-1},x_n)q(Tx_{n-1},Tfx_{n-1}) \\ &\quad + r(x_{n-1},x_n)q(Tx_n,Tfx_n)+t(x_{n-1},x_n)[q(Tx_{n-1},Tfx_n)+q(Tx_n,Tfx_{n-1})] \\ &= k(x_{n-1},x_n)q(Tx_{n-1},Tx_n)+l(x_{n-1},x_n)q(Tx_{n-1},Tx_n) \\ &\quad + r(x_{n-1},x_n)q(Tx_n,Tx_{n+1})+t(x_{n-1},x_n)[q(Tx_{n-1},Tx_{n+1})+q(Tx_n,Tx_n)] \\ &\preccurlyeq (k+l+t)(x_{n-1},x_n)q(Tx_{n-1},Tx_n)+(r+t)(x_{n-1},x_n)q(Tx_n,Tx_{n+1}). \end{aligned}$$

Consequently

$$q(Tx_n,Tx_{n+1}) \preccurlyeq \frac{k(x_{n-1},x_n)+l(x_{n-1},x_n)+t(x_{n-1},x_n)}{1-r(x_{n-1},x_n)-t(x_{n-1},x_n)}q(Tx_{n-1},Tx_n). \tag{3}$$

Using (2), we have

$$\frac{k(x,y)+l(x,y)+t(x,y)}{1-r(x,y)-t(x,y)} \le \lambda$$

for all $x, y \in X$. Thus, from (3), it follows that

$$q(Tfx_{n-1},Tfx_n) = q(Tx_n,Tx_{n+1}) \preccurlyeq \lambda q(Tx_{n-1},Tx_n).$$

Following arguments similar to those given above, we obtain

$$q(Tfx_n, Tfx_{n+1}) = q(Tx_{n+1}, Tx_{n+2}) \preccurlyeq \lambda q(Tx_n, Tx_{n+1}),$$

where

$$\frac{k(x,y)+r(x,y)+t(x,y)}{1-l(x,y)-t(x,y)} \le \lambda$$

for all $x, y \in X$. Therefore for all n,

$$\begin{aligned} q(Tx_n, Tx_{n+1}) &\preccurlyeq \lambda q(Tx_{n-1}, Tx_n) \\ &\preccurlyeq \lambda^2 q(Tx_{n-2}, Tx_{n-1}) \\ &\vdots \\ &\preccurlyeq \lambda^n q(Tx_0, Tx_1). \end{aligned} \tag{4}$$

Let $m > n \ge 1$. Then it follows that

$$\begin{aligned} q(Tx_n, Tx_m) &\preccurlyeq q(Tx_n, Tx_{n+1}) + q(Tx_{n+1}, Tx_{n+2}) + \cdots + q(Tx_{m-1}, Tx_m) \\ &\preccurlyeq (\lambda^n + \lambda^{n+1} + \cdots + \lambda^{m-1}) q(Tx_0, Tx_1) \\ &\preccurlyeq \frac{\lambda^n}{1-\lambda} q(Tx_0, Tx_1) \to \theta \text{ as } n \to \infty. \end{aligned}$$

Thus, Lemma 2.9(3) shows that $\{Tx_n\}$ is a Cauchy sequence in X. Since X is complete, there exists $Z_x \in X$ such that $Tx_n \to Z_x$ as $n \to \infty$. Thus

$$\lim_{n\to\infty} Tfx_n = Z_x. \tag{5}$$

Since T is subsequentially convergent, $\{fx_n\}$ has a convergent subsequence. Thus, there exist $\omega_{x_0} \in X$ such that

$$\lim_{n\to\infty} fx_{n_i} = \omega_{x_0}. \tag{6}$$

Since T is continuous, we obtain

$$\lim_{n\to\infty} Tfx_{n_i} = T\omega_{x_0}. \tag{7}$$

From (5) and (7) and using the injectivity of T, there exists a $\omega_{x_0} \in X$ such that $T\omega_{x_0} = Z_x$. Then by (q_3), we have

$$q(Tfx_n, T\omega_{x_0}) \preccurlyeq \frac{\mu^n}{1-\mu} q(Tx_0, Tx_1). \tag{8}$$

On the other hand by using (1), we have

$$\begin{aligned} q(T\omega_{x_0}, Tf\omega_{x_0}) &\preccurlyeq q(T\omega_{x_0}, Tfx_n) + q(Tfx_n, Tf\omega_{x_0}) \\ &= q(T\omega_{x_0}, Tx_{n+1}) + q(Tfx_n, Tf\omega_{x_0}) \\ &\preccurlyeq q(T\omega_{x_0}, Tx_{n+1}) + k(x_n, \omega_{x_0}) q(Tx_n, T\omega_{x_0}) + l(x_n, \omega_{x_0}) q(Tx_n, Tfx_n) \\ &\quad + r(x_n, \omega_{x_0}) q(T\omega_{x_0}, Tf\omega_{x_0}) + t(x_n, \omega_{x_0})[q(Tx_n, Tf\omega_{x_0}) + q(T\omega_{x_0}, Tfx_n)] \\ &= q(T\omega_{x_0}, Tx_{n+1}) + k(x_n, \omega_{x_0}) q(Tx_n, T\omega_{x_0}) + l(x_n, \omega_{x_0}) q(Tx_n, Tx_{n+1}) \\ &\quad + r(x_n, \omega_{x_0}) q(T\omega_{x_0}, Tf\omega_{x_0}) + t(x_n, \omega_{x_0})[q(Tx_n, Tf\omega_{x_0}) + q(T\omega_{x_0}, Tx_{n+1})] \end{aligned}$$

$$
\begin{aligned}
&\preceq q(T\omega_{x_0},Tx_{n+1})+k(x_n,\omega_{x_0})q(Tx_n,T\omega_{x_0})+l(x_n,\omega_{x_0})q(Tx_n,Tx_{n+1})\\
&\quad+r(x_n,\omega_{x_0})q(T\omega_{x_0},Tf\omega_{x_0})+t(x_n,\omega_{x_0})[q(Tx_n,T\omega_{x_0})\\
&\quad+q(T\omega_{x_0},Tf\omega_{x_0})+q(T\omega_{x_0},Tx_{n+1})]\\
&=q(T\omega_{x_0},Tx_{n+1})+(k+t)(x_n,\omega_{x_0})q(Tx_n,T\omega_{x_0})+l(x_n,\omega_{x_0})q(Tx_n,Tx_{n+1})\\
&\quad+(r+t)(x_n,\omega_{x_0})q(T\omega_{x_0},Tf\omega_{x_0})+t(x_n,\omega_{x_0})q(T\omega_{x_0},Tx_{n+1})]\\
&\preceq \frac{1}{1-\lambda}q(T\omega_{x_0},Tx_{n+1})+\frac{\lambda}{1-\lambda}q(Tx_n,T\omega_{x_0})\\
&\quad+\frac{\lambda}{1-\lambda}q(Tx_n,Tx_{n+1})+\frac{\lambda}{1-\lambda}q(T\omega_{x_0},Tx_{n+1})\\
&=A_1q(T\omega_{x_0},Tx_{n+1})+A_2q(Tx_n,T\omega_{x_0})+A_3\lambda^{n+1}+A_4q(T\omega_{x_0},Tx_{n+1})
\end{aligned}
$$

where $A_1=\frac{1}{1-\lambda}$, $A_2=\frac{\lambda}{1-\lambda}$, $A_3=\frac{1}{1-\lambda}q(Tx_0,Tx_1)$ and $A_4=\frac{\lambda}{1-\lambda}$.

Let $\theta\ll c$. Since $\lambda^{n+1}\to\theta$ and $Tx_{n_i}\to T\omega_{x_0}$ as $i\to\infty$ there exists a natural number n_0 such that for each $i\geq n_0$, we have

$$q(T\omega_{x_0},Tx_{n+1})\ll\frac{c}{4A_1},\quad q(Tx_n,T\omega_{x_0})\ll\frac{c}{4A_2},\quad \lambda^{n_i}\ll\frac{c}{4A_3},\quad q(T\omega_{x_0},Tx_{n+1})\ll\frac{c}{4A_4}.$$

By (q_4), we obtain

$$q(T\omega_{x_0},Tf\omega_{x_0})\ll\frac{c}{4}+\frac{c}{4}+\frac{c}{4}+\frac{c}{4}=c.$$

Thus $q(T\omega_{x_0},Tf\omega_{x_0})\ll c$ for each $c\in\operatorname{int}P$. Using Lemma 2.6(2), we obtain $q(T\omega_{x_0},Tf\omega_{x_0})=\theta$; that is $T\omega_{x_0}=Tf\omega_{x_0}$. Since T is one to one, $f\omega_{x_0}=\omega_{x_0}$.

Finally, suppose there is another fixed point ω_{x_1} of f, then we have

$$
\begin{aligned}
q(T\omega_{x_0},Tf\omega_{x_1})&=q(Tf\omega_{x_0},Tf\omega_{x_1})\\
&\preceq k(\omega_{x_0},\omega_{x_1})q(T\omega_{x_0},T\omega_{x_1})+l(\omega_{x_0},\omega_{x_1})q(T\omega_{x_0},Tf\omega_{x_0})\\
&\quad+r(\omega_{x_0},\omega_{x_1})q(T\omega_{x_1},Tf\omega_{x_1})\\
&\quad+t(\omega_{x_0},\omega_{x_1})[q(T\omega_{x_0},Tf\omega_{x_1})+q(T\omega_{x_1},Tf\omega_{x_0})\\
&=(k+2t)(\omega_{x_0},\omega_{x_1})q(T\omega_{x_0},T\omega_{x_1})\\
&\preceq\lambda d(T\omega_{x_0},T\omega_{x_1}).
\end{aligned}
$$

Using Lemma 2.6(1), it follows that $q(T\omega_{x_0},T\omega_{x_1})=\theta$, which implies that $T\omega_{x_0}=T\omega_{x_1}$. Since T is one to one $\omega_{x_0}=\omega_{x_1}$. Thus f has a unique fixed point. Now if T is sequentially convergent, then we can replace n_i by n. Thus, we have

$$\lim_{n\to\infty}fx_n=\omega_{x_0}.$$

Therefore, from Definition 2.11(b), the sequence $\{fx_n\}$ converges to ω_{x_0}. □

The following result is obtained from Theorem 3.1.

Corollary 3.2. *Let (X,d) be a complete cone metric space, P a solid cone and q be a c-Distance on X. In addition let $T:X\to X$ is a continuous and one to one mapping and $f:X\to X$ be a map* *satisfying*

$$q(Tfx,Tfy) \preccurlyeq \alpha q(Tx,Ty) + \beta[q(Tx,Tfx) + q(Ty,Tfy)] + \gamma[q(Tx,Tfy) + q(Ty,Tfx)] \tag{9}$$

for all $x, y \in X$ *where*

$$\alpha, \beta, \gamma \geq 0 \text{ and } \alpha + 2\beta + 2\gamma \leq 1 \tag{10}$$

that is, f *be a T-contraction. Then*

(1) *For each* $x_0 \in X$, $\{Tf^n x_0\}$ *is a Cauchy sequence.*
(*Define the iterate sequence* $\{x_n\}$ *by* $x_{n+1} = f^{n+1}x_0$.)

(2) *There exists a* $Z_{x_0} \in X$ *such that* $\lim_{n\to\infty} Tf^n x_0 = Zx_0$.

(3) *If* T *is subsequentially convergent, then* $\{f^n x_0\}$ *has a convergent subsequence.*

(4) *There exists a unique* $\omega_{x_0} \in X$ *such that* $f\omega_{x_0} = \omega_{x_0}$; *that is,* f *has a unique fixed point.*

(5) *If* T *is sequentially convergent, then, for each* $x_0 \in X$ *the sequence* $\{f^n x_0\}$ *converges to* ω_{x_0}.

Proof. Corollary 3.2 follows from Theorem 3.1 by setting $k = \alpha$, $l = r = \beta$ and $t = \gamma$. □

4. Conclusion

In this paper, we have established unique fixed point for T- contraction mapping under the concept of c-Distance in cone metric spaces.

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Competing Interests

The authors declare that they have no competing interests.

Authors' Contributions

All the authors contributed significantly in writing this article. The authors read and approved the final manuscript.

References

[1] M. Abbas and G. Jungck, Common fixed point results for noncommuting mappings without continuity in cone metric spaces, *J. Math. Anal. Appl.* **341** (2008), 416 – 420, DOI: 10.1016/j.jmaa.2007.09.070.

[2] M. Abbas and B. E. Rhoades, Fixed and periodic point results in cone metric spaces, *Appl. Math. Lett.* **22** (2009), 511 – 515, DOI: 10.1016/j.aml.2008.07.001.

[3] A. Beiranvand, S. Moradi, M. Omid and H. Pazandeh, *Two fixed point theorem for special mapping*, arXiv:0903.1504v1[math.FA], url: `https://arxiv.org/pdf/0903.1504.pdf`.

[4] Y. J. Cho, R. Saadati and S. Wang, Common fixed point theorems on generalized distance in ordered cone metric spaces, *Comut. Math. Appl.* **61** (2011), 1254 – 1260, DOI: 10.1016/j.camwa.2011.01.004.

[5] A. K. Dubey, R. Shukla and R. P. Dubey, Common fixed point theorems for T-reich contraction mapping in cone metric spaces, *Advances in Fixed Point Theory* **3**(2) (2013), 315 – 326, URL: `http://www.scik.org/index.php/afpt/article/view/937`.

[6] A. K. Dubey, R. Shukla and R. P. Dubey, Common fixed point theorem for generalized T-hardy-rogers contraction mapping in a cone metric space, *Advances in Inequalities and Applications* **2014** (2014), 18, 1 – 16,URL: `http://www.scik.org/index.php/aia/article/view/1522`.

[7] A. K. Dubey, R. Shukla and R. P. Dubey, Cone metric spaces and fixed point theorems of generalized T-Zamfirescu mappings, *International Journal of Applied Mathematical Research* **2**(1) (2013), 151 – 156, DOI: 10.14419/ijamr.v2i1.650.

[8] A. K. Dubey, R. Verma and R. P. Dubey, Cone metric spaces and fixed point theorems of contractive mapping for c-distance, *International Journal of Mathematics And its Applications* **3**(1) (2015), 83 – 88, URL: `http://www.ijmaa.in/papers/3110.pdf`.

[9] A. K. Dubey and U. Mishra, Some fixed point results for c-distance in cone metric spaces, *Nonlinear Funct. Anal. & Appl.* **22**(2) (2017), 275 – 286.

[10] A. K. Dubey and U. Mishra, Some fixed point results of single-valued mapping for c-distance in TVS-cone metric spaces, *Filomat* **30**, 11 (2016), 2925 – 2934, DOI: 10.2298/FIL1611925D.

[11] M. Filipović, L. Paunović, S. Radenović and M. Rajović, Remarks on "Cone metric spaces and fixed point theorems of T-Kannan and T-Chatterjea contractive mappings", *Math. Comput. Modelling* **54** (2011), 1467 – 1472, DOI: 10.1016/j.mcm.2011.04.018.

[12] Z. M. Fadail, A. G. B. Ahmad and L. Paunović, New fixed point results of single valued mapping for c-distance in cone metric spaces, *Abstract and Applied Analysis* **2012**(2012), Article ID 639713, 1 – 12, DOI: 10.1155/2012/639713.

[13] Z. M. Fadail and S. M. Abusalim, T-Reich contraction and fixed point results in cone metric spaces with c-distance, *International Journal of Mathematical Analysis* **11**(8) (2017), 397 – 405, DOI: 10.12988/ijma.2017.7338.

[14] L. G. Huang and X. Zhang, Cone metric spaces and fixed point theorems of contractive mappings, *J. Math. Anal. Appl.* **332**(2007), 1468 – 1476, DOI: 10.1016/j.jmaa.2005.03.087.

[15] G. Jungck, S. Radenović, S. Radojević and V. Rakoćević, Common fixed point theorems for weakly compatible pairs on cone metric spaces, *Fixed Point Theory and Applications* **2009** (2009), Article ID 643840, DOI: 1155/2009/643840.

[16] H. Rahimi, B. E. Rhoades, S. Radenović and G. S. Rad, Fixed and periodic point theorems for T-contractions on cone metric spaces, *Filomat* **27**(5) (2013), 881 – 888, DOI: 10.2298/FIL1305881R.

[17] W. Sintunavarat, Y. J. Cho and P. Kumam, Common fixed point theorems for c-distance in ordered metric spaces, *Comput. Math. Appl.* **62**(2011), 1969 – 1978, DOI: 10.1016/j.camwa. 2011.06.040.

[18] S. Wang and B. Guo, Distance in cone metric spaces and common fixed point theorems, *Applied Mathematical Letters* **24** (2011), 1735 – 1379, DOI: 10.1016/j.aml.2011.04.031.