

A Cadaveric Study of Superficial Palmar Arch with Surgical Importance

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ABSTRACT

Introduction: Arterial supply of hand is by two arterial anastomotic arches formed by radial and ulnar arteries and their branches. The anastomoses between the branches of radial and ulnar arteries such as palmar carpal and dorsal carpal arches at the wrist and superficial and deep palmar arches in the palm, maintain a rich arterial supply to the wrist and palm. Effective collateral circulation in palm is essential in peripheral arterial diseases such as Raynaud's disease and in harvesting radial artery or the ulnar artery for Coronary Artery Bypass Graft (CABG) surgery.

Aim: To observe the variations in the formation of superficial palmar arch.

Materials and Methods: A descriptive study was performed on 45 formalin fixed upper limbs of both sex in the Department of Anatomy, JSS Medical College, Mysuru, Karnataka, India. The

study was conducted during routine dissection of upper limbs for undergraduates as per the Cunningham's manual for practical anatomy. Few rare variations in the formation of superficial palmar arch and the arterial pattern of hand were noticed. The variations found were classified according to Coleman and Anson classification.

Results: Out of 45 limbs, complete arch was found in 36 limbs and incomplete arch in nine limbs. In complete arch type, we found an arterial arcade, bifurcation of ulnar artery and in incomplete arch type, radial-radial anastomosis. Another rare findings of highly tortuous ulnar artery in forearm and in the palm.

Conclusion: The findings in the variations of superficial palmar arch are essential in microvascular surgery, forearm fasciocutaneous flap, radial artery and ulnar artery harvesting in coronary artery bypass graft procedure.

Keywords: Anastomosis, Radial artery, Revascularisation, Ulnar artery, Vascular occlusive disease

INTRODUCTION

The radial and ulnar arteries and their terminal branches in the form of two arterial arches, superficial and deep palmar arches supply the palm [1]. Superficial palmar arch is the main arterial supply of palm which is formed by the continuation of ulnar artery in the palm anastomosing with the superficial palmar branch of radial artery, from which the palmar digital arteries arise. Ulnar artery enters palm superficial to the flexor retinaculum along with the ulnar nerve on its medial side lateral to pisiform bone. Then, it turns laterally after passing medial to the hook of the hamate to form the superficial palmar arch [1]. The superficial palmar arch is formed entirely by ulnar artery in one-third of cases, in another third it is completed by the superficial palmar branch of radial artery and a third by branches of radial artery, arteria princeps pollicis or arteria radialis indicis or by the median artery [1]. It gives one proper palmar digital artery for the ulnar side of the little finger and three common palmar digital arteries. The three common palmar digital arteries which runs on the second to fourth lumbricals, receives palmar metacarpal arteries from the deep palmar arch, and divide into two proper palmar digital arteries.

Proper palmar digital arteries run along the adjacent sides of all digits. Palmar digital arteries supply the metacarpophalangeal joints, interphalangeal joints, nutrient branches to phalanges, soft parts including the matrices of the nails. They are the main digital arteries, since the dorsal digital arteries are small [1]. There are extensive connections between the superficial and deep palmar arches and between the dorsal and palmar digital arteries. The formation of superficial palmar arch is highly variable with various types of contributions coming from ulnar, radial and median arteries [2,3]. The variations in the formation of the superficial palmar arch was first reported by Jaschtschinski SN in 1897 and classified into complete and incomplete arches [4].

The main reason for variations in the formation of superficial palmar arch is the radial artery whereas the ulnar artery normally remains

constant and variations seem to be more common within the complete type of superficial palmar arch [5-9].

Several studies have reported that the variations in the formation of superficial palmar arch, being one of the most challenging region and palmar arterial arches has strongly attracted not only clinicians, radiologists even anatomists [10-13]. It is during routine dissection for undergraduate students sometimes that very rare variations in the pattern of superficial palmar arch formation and the distribution of digital branches from the arch supplying the palm were noticed. These variations have to be reported in order to understand the complex but very fine structure of arterial patterns of the palm. Detailed knowledge of which is essential to perform innovative microvascular procedures in reconstructive plastic surgeries of palm, surgical interventions and successful result of the same [14].

The objective of this study was to find out the incidence of anatomical variations in the pattern of superficial palmar arch formation and distribution of digital branches from the arch supplying the palm and describe the variation unknown, which is not reported in the literature so far.

MATERIALS AND METHODS

It was a descriptive study, started in September 2019 for undergraduate (2019-2020) batch and completed by November 2020. It was done in JSS Medical College, Anatomy Department, Gross Anatomy Dissection Hall, Mysuru, Karnataka, India. A total of 45 upper limbs of both sex (12 females and 33 males) from embalmed human cadavers, used for routine dissection by undergraduate students, Jagadguru Sri Shivaratheeshwara Medical College, Mysuru were dissected. Ethics Committee Approval was obtained for this study. (JSSMC/IEC/141020/49/NCT/2020-21).

Inclusion criteria: Cadavers which were given to undergraduate students for dissection of upper limbs were included for the study.

Exclusion criteria: Damaged limbs in the region of forearm and palm were excluded from the study.

The dissection of palm was performed according to Cunningham's manual of practical anatomy volume I [15]. The branches of radial and ulnar arteries were traced, cleaned and variations were noted. Photos of the dissected palm were taken and data were classified according to Coleman SS and Anson BJ classification as follow [6]:

- Complete arch is when there is anastomosis between the arteries that forms the arch.
Complete arch further divided into:
Type A: Radial-ulnar arch, by ulnar artery and superficial palmar branch of radial artery.
Type B: Ulnar arch arch, formed entirely by ulnar artery.
Type C: Median-ulnar arch, by ulnar artery and persistent median artery.
Type D: Radial-median-ulnar arch, all three arteries ending in the arch.
Type E: Ulnar artery and completed by a large branch from deep arch.
- Incomplete arch is when there is no anastomosis between the arteries forming the arch [4-7].
Incomplete arch further divided into:
Type F: Mainly by ulnar artery, not supplying thumb and index fingers.
Type G: By ulnar artery and branches of radial artery.
Type H: Persistent median and ulnar arteries
Type I: Radial, median and ulnar artery all giving branches to digits separately.

STATISTICAL ANALYSIS

Results were expressed in terms of frequency and percentages.

RESULTS

Out of 45 limbs, 36 limbs showed complete superficial palmar arch and nine limbs showed incomplete arch [Table/Fig-1].

Type	Right	Left	Total
Complete	19	17	36
Incomplete	06	03	09

[Table/Fig-1]: Results by classification.

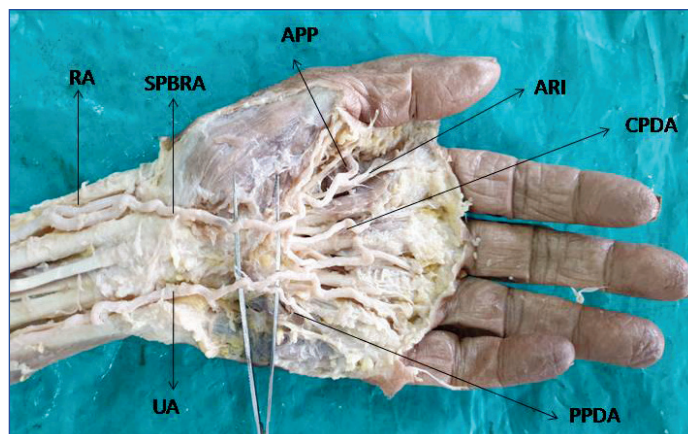
Complete Types of Arches

A complete type of arch was found in 36 (80%) palms. It was subdivided into four types according to Coleman SS and Anson BJ classification.

1. Type A- Radial-ulnar type: This is classic type formation of superficial palmar arch by ulnar artery and radial artery. This type was observed in 20 hands but showed some modifications than the usual arterial pattern.

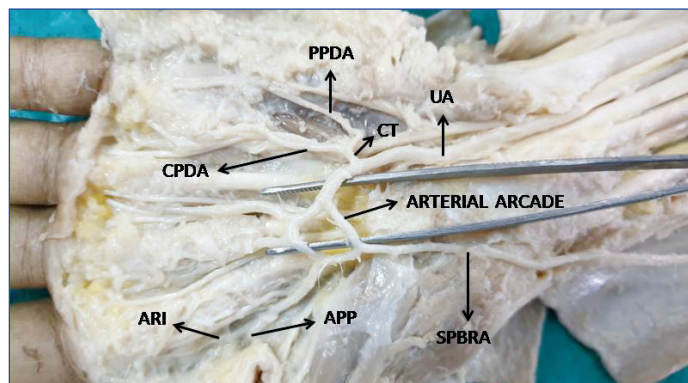
Subtype I- the classic type, superficial palmar arch by ulnar artery and superficial palmar branch of radial artery was seen in 15 (33%) hands. In one cadaver, the superficial palmar branch of radial artery was arising in the lower third of forearm, passing superficial to the tendon of flexor carpi radialis and almost same size as ulnar artery completed the arch, bilaterally. In addition to three common palmar and one proper palmar digital arteries, the superficial palmar arch gave another common palmar digital artery to the first web space which divided into two branches for the radial side of the index and thumb representing the arteria radialis indicis and arteria princeps pollicis of the radial artery [Table/Fig-2].

Modification or deviations from the normal pattern: Arterial arcade: In two limbs, the superficial palmar branch of radial artery along with ulnar artery forms the superficial palmar arch, but the anastomosis between the two arteries formed an arterial arcade like the arterial arcades of jejunum and ileum and gave rise to the proper palmar digital arteries like the vasa recta of jejunum and ileum. In one limb,



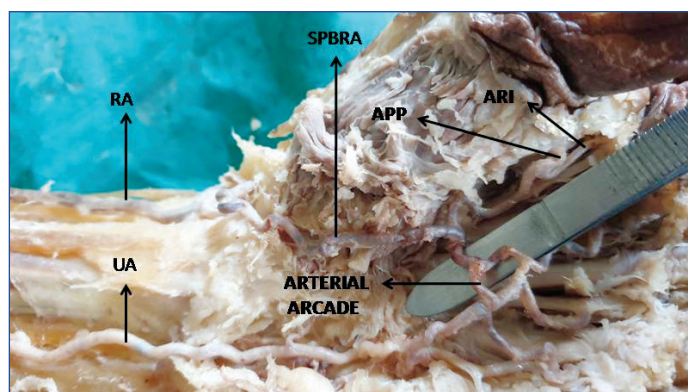
[Table/Fig-2]: Palm showing Type A, complete superficial palmar arch.
UA: Ulnar artery; RA: Radial artery; SPBRA: Superficial palmar branch of radial artery; CPDA: Common palmar digital artery; PPDA: Proper palmar digital artery; APP: Arteria princeps pollicis; ARI: Arteria radialis indicis

the arterial arcade gave rise to three proper palmar digital arteries to lateral 3 1/2 digits. The arch gave rise to one common trunk, which divided into one proper palmar digital artery, which supplied the ulnar side of the ring finger and radial side of the little finger and one proper palmar digital artery which supplied the ulnar side of the little finger [Table/Fig-3].



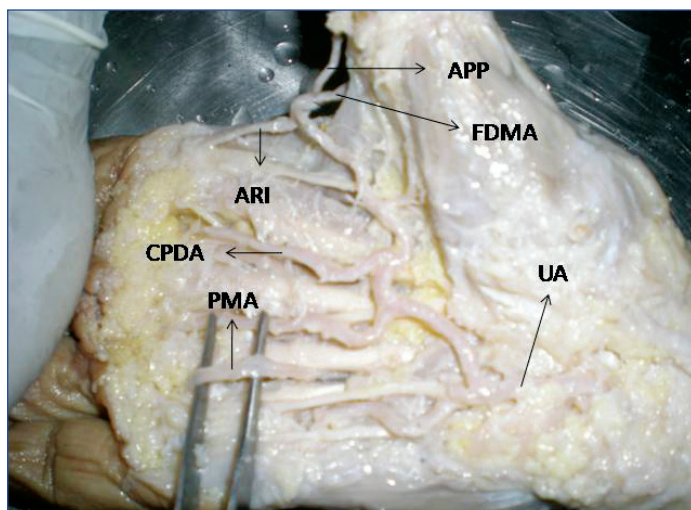
[Table/Fig-3]: Palm showing Type A, complete superficial palmar arch with an arterial arcade.
UA: Ulnar artery; RA: Radial artery; SPBRA: Superficial palmar branch of radial artery; CT: Common trunk for CPDA: Common palmar digital artery and PPDA: Proper palmar digital artery; APP: Arteria princeps pollicis; ARI: Arteria radialis indicis

In another limb, the superficial palmar branch of radial artery and ulnar artery formed the arterial arcade, and from the arterial arcade only two common palmar digital arteries, which supplied the middle finger, lateral side of ring finger and medial side of index finger. The common palmar digital branches arising from the arch supplied the medial side of the ring finger and the little finger. But the thumb and radial side of index finger are supplied from the proper palmar digital artery arising from the superficial palmar branch of radial artery before forming the arterial arcade [Table/Fig-4].



[Table/Fig-4]: Palm showing Type A, complete superficial palmar arch with an arterial arcade.
UA: Ulnar artery; RA: Radial artery; SPBRA: Superficial palmar branch of radial artery; APP: Arteria princeps pollicis; ARI: Arteria radialis indicis

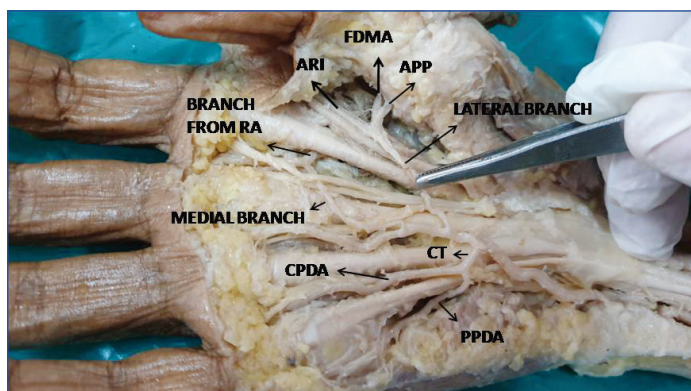
Subtype II- Superficial palmar arch was formed by the continuation of ulnar artery in the palm and completed by the first dorsal metacarpal artery. Ulnar artery was anastomosing with the first dorsal metacarpal artery after giving arteria princeps pollicis and arteria radialis indicis branches. This type was seen in five hands (11%). In one specimen, the palmar digital branches from the arch supplied the remaining digits except the medial side of ring finger and lateral side of little finger which was supplied by the palmar metacarpal artery from the deep palmar arch [Table/Fig-5].



[Table/Fig-5]: Palm showing Type A, Complete superficial palmar arch formed by ulnar artery and first dorsal metacarpal artery.

FDMA: First dorsal metacarpal artery; CPDA: Common palmar digital artery; APP: Arteria princeps pollicis; ARI: Arteria radialis indicis; PMA: Palmar metacarpal artery from deep palmar arch

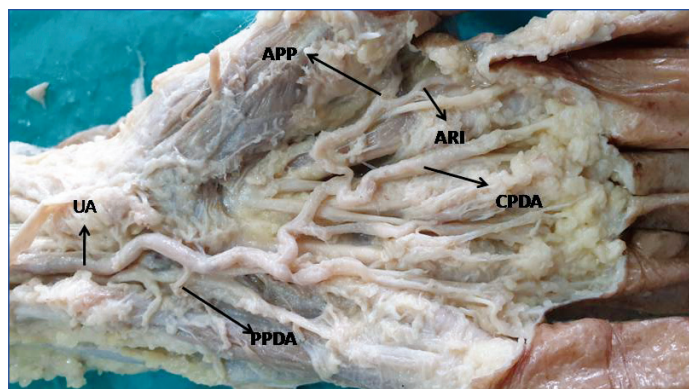
In one limb, the ulnar artery bifurcated into two branches in the middle of the palm. The lateral branch continued its lateral course towards the first web space and anastomosed with the first dorsal metacarpal artery after giving arteria princeps pollicis and arteria radialis indicis branches. The medial branch joined a branch coming from the radial artery just proximal to second web space. This branch of radial artery later continued as the proper palmar digital artery supplying the medial side of index and lateral side of middle fingers respectively. The arch gave one common palmar digital artery which supplied the adjacent sides of middle and ring fingers and one common trunk which inturn divided into common palmar digital and proper palmar digital arteries for adjacent sides of ring and little fingers and ulnar side of little finger respectively [Table/Fig-6].



[Table/Fig-6]: Palm showing bifurcation of the superficial palmar arch.

UA: Ulnar artery; FDMA: First dorsal metacarpal artery; CT: Common trunk for CPDA: Common palmar artery and PPDA: Proper palmar digital artery; APP: Arteria princeps pollicis; ARI: Arteria radialis indicis, Branch from RA: Radial artery

2. Type B- Ulnar type: This type of superficial palmar arch is formed by the continuation of ulnar artery alone. The ulnar artery gave origin to the common palmar digital arteries as well as the arteria princeps pollicis and arteria radialis indicis which are usually branches of radial artery, supplies the radial side of the index and the thumb without any connection with other arteries. This type was observed in 14 hands [Table/Fig-7].

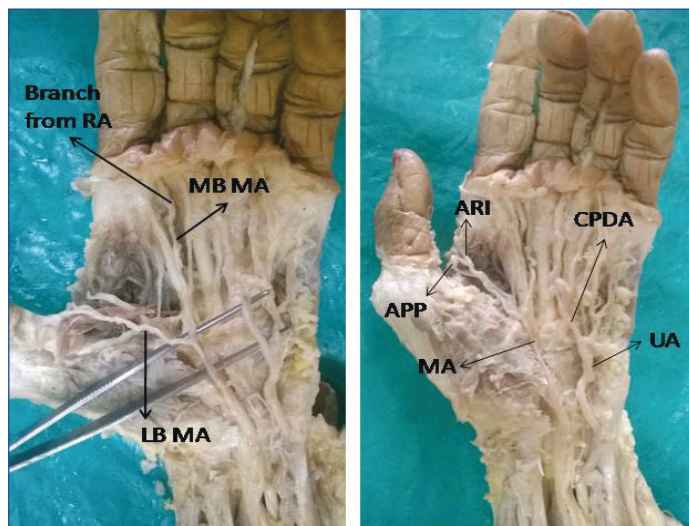


[Table/Fig-7]: Palm showing Type B complete superficial palmar arch formed only by ulnar artery.

UA: Ulnar artery; CPDA: Common palmar digital artery and PPDA: Proper palmar digital artery; APP: Arteria princeps pollicis; ARI: Arteria radialis indicis

3. Type C- Median-ulnar type: This type of superficial palmar arch is formed by the continuation of ulnar artery in the palm and completed by the persistent median artery. This was observed in one hand.

4. Type D: Radial-median-ulnar type: This type of superficial palmar arch is formed by the anastomosis between the branches of radial artery, persistent median artery and the ulnar artery. This was observed in one hand. The ulnar artery gave origin to two common palmar digital and one proper palmar digital arteries which supplied medial 2 1/2 digits. Median artery after entering palm divided into two branches. The lateral branch divided into arteria princeps pollicis and arteria radialis indicis in the first web space. Medial branch passed medial to the tendons of index finger and joined a branch coming from the radial artery in the second web space. The medial branch of median artery and branch of radial artery anastomosis supplied the ulnar side of index and radial side of middle fingers [Table/Fig-8]. Type E was not found in the present study.



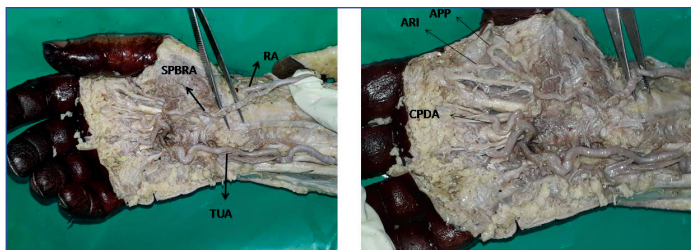
[Table/Fig-8]: Palm showing Type D superficial palmar arch formed by the radial artery, median artery and ulnar artery.

UA: Ulnar artery; MA: Median artery; CPDA: Common palmar digital artery; APP: Arteria princeps pollicis; ARI: Arteria radialis indicis, LBMA: Lateral branch of median artery; MBMA: Medial branch of median artery anastomosing with branch of radial artery

Incomplete Types of Arches

An incomplete type of arch was found in 9 (20%) palms. It was subdivided into two types according to Coleman SS and Anson BJ classification.

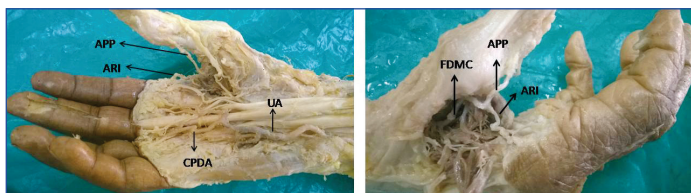
1. Type F – mainly by ulnar artery, not supplying the radial side of index and thumb. This type of incomplete arch was formed by the continuation of ulnar artery and superficial palmar branch of radial artery with no anastomosis. This was observed in two hands. The radial side of index and thumb were supplied by the superficial palmar branch of the radial artery [Table/Fig-9].



[Table/Fig-9]: Palm showing Type F incomplete superficial palmar arch and highly tortuous ulnar artery.

TUA: Tortuous ulnar artery; RA: Radial artery; SPBRA: Superficial palmar branch of radial artery; CPDA: Common palmar digital artery; APP: Arteria princeps pollicis; ARI: Arteria radialis indicis

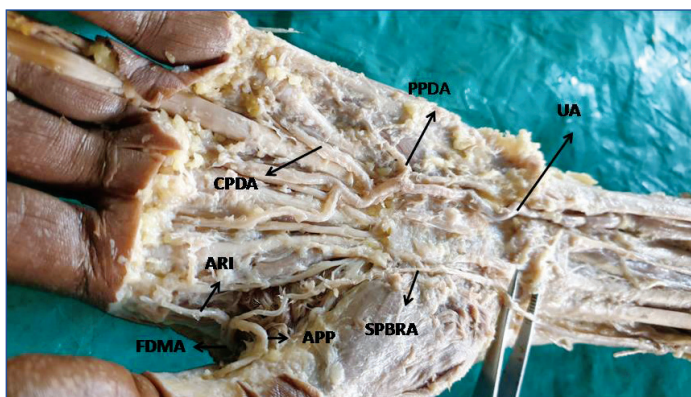
2. Type G- Ulnar-radial type: This type of incomplete arch is formed by the continuation of ulnar artery in the palm and branches of radial artery with no anastomosis. This was observed in seven hands. In two specimens, the ulnar artery and radial artery branches supplied medial 2 1/2 and lateral 2 1/2 digits, respectively with no anastomosis. In two specimens, the ulnar artery and radial artery branches supplied medial 3 1/2 and lateral 1 1/2 digits, respectively with no anastomosis. In another three specimens, the palmar continuation of first dorsal metacarpal artery which divided into two branches to index and thumb in the first intermetacarpal space to supply index and thumb [Table/Fig-10].



[Table/Fig-10]: Palm showing Type G incomplete superficial palmar arch.

UA: Ulnar artery; FDMA: First dorsal metacarpal artery; CPDA: Common palmar digital artery; APP: Arteria princeps pollicis; ARI: Arteria radialis indicis

In one specimen the thin superficial palmar branch of radial artery was anastomosing with a branch of first dorsal metacarpal artery. First dorsal metacarpal artery also gave the arteria princeps pollicis and arteria radialis indicis branches to index finger and thumb. The thenar area, thumb and radial side of index were supplied by this radio-radial anastomosis [Table/Fig-11].



[Table/Fig-11]: Palm showing Type G incomplete superficial palmar arch.

UA: Ulnar artery; SPBRA: Superficial palmar branch of radial artery; CPDA: Common palmar digital artery; PPDA: Proper palmar digital artery; APP: Arteria princeps pollicis; ARI: Arteria radialis indicis

Apart from the complete and incomplete arches we also observed highly tortuous ulnar artery in 19 specimens. The ulnar artery was highly tortuous in the forearm and even in the palm resulting in tortuous superficial palmar arch [Table/Fig-9], ([Table/Fig-9] is common figure for Type F and tortuous ulnar artery).

We did not get Type H and Type I incomplete superficial palmar arches in present study.

DISCUSSION

In the present study, the superficial palmar arch was divided into complete and incomplete arches. Complete superficial palmar

arches were observed in 80% and incomplete arches in 20%, respectively [Table/Fig-12].

Types	Subtype	n (%)
Complete (80%)	Type A, Radial-ulnar	20 (44.5%)
	Type B, Ulnar	14 (31.1%)
	Type C, Median-ulnar	01 (2.2%)
	Type D, Radial-median-ulnar	01 (2.2%)
Incomplete (20%)	Type F, mainly by ulnar artery, not supplying thumb and index fingers.	02 (4.4%)
	Type G, Radial-ulnar without anastomosis	07 (15.6%)

[Table/Fig-12]: Incidences of different types of superficial palmar arch.

Presence of complete arch varies from 45-96.4% [16,17]. Incomplete arch included Type F (4.4%) and Type G (15.5%). The presence of an incomplete arch varies from 3-34% in the literature [7,18].

The most commonly described type of formation of superficial palmar arch is radio-ulnar in the literature or in the textbooks [1,5]. In the present study, this common classical type (Type A) was observed in 44.5% of cases and divided into two subtypes, subtype I (31.1%) and subtype II (11%).

The superficial palmar branch of radial artery and the ulnar artery forming the arterial arcade is one of the rare variations observed in two specimens. This variation has been reported by Madhyastha S et al., but they have not mentioned it as an arterial arcade, instead they have mentioned the formation of superficial palmar arch by superficial palmar branch of radial artery and ulnar artery and a transverse branch proximal to the arch connecting the superficial palmar branch of radial artery and the ulnar artery [10]. This type of anastomosis may distribute blood equally to all the digits.

The ulnar artery anastomosing with the first dorsal metacarpal branch of the radial artery (subtype II), which was found in 11% of cases, had rarely been reported in the literature. This subtype II has also been reported by Bilge O et al., (28%) and Fazan VP et al., (26.5%) and Ruengsakulrach P et al., (18%) of cases [12,13,18].

Another rare variation observed in the study was bifurcation of the superficial palmar arch or duplication of the superficial palmar arch. Patnaik VVG et al., have reported superficial palmar arch duplication and the arch was formed by the ulnar artery and persistent median artery. They have mentioned it consists of proximal complete arch formed by the median and ulnar arteries with no digital branches arising from it and distal incomplete arch formed by the median and ulnar arteries giving the digital branches [19]. Rapotra M et al., also reported the presence of double superficial palmar arch as having proximal and distal arches in their study. Proximal arch is by a thin branch from the lateral side of ulnar artery which terminates by giving arteria princeps pollicis and arteria radialis indicis in the first web space. Distal arch is by ulnar artery which gave rise to the three common and one proper palmar digital arteries [20]. In present study, also the proximal arch gave arteria princeps pollicis and arteria radialis indicis branches in the first web space but it anastomosed with first dorsal metacarpal artery and distal arch gave rise to digital arteries. Both proximal and distal arches were complete, since the bifurcated ulnar artery was anastomosing with the branches of radial artery in the first and second web spaces.

The variant origin of arteria princeps pollicis and arteria radialis indicis from ulnar artery in type B arch, from superficial palmar arch in type A subtype I and from first dorsal metacarpal artery in type A subtype II makes hand surgeries difficult in traumatic situations [8].

Persistent median artery can contribute significantly in the formation of superficial palmar arch, complete or incomplete and arterial supply to the hand. As it passes through the carpal tunnel it has a superficial course and might get damaged during carpal tunnel release [21].

In incomplete arch, type G showed slight deviation than the normal description. The superficial palmar branch of the radial artery was

anastomosing with first dorsal metacarpal artery. The thenar region, thumb and radial side of index finger were supplied by the radio-radial anastomosis. This was not reported in the literature.

Present study confirmed the findings of Coleman SS and Anson BJ, they found complete superficial palmar arch in 78.5% of cases [6]. We observed the complete superficial palmar arch in 80% of the cases.

The classic type of superficial palmar arch (type A) formed by the superficial palmar branch of the radial artery and ulnar artery was found in 34.5% of hands, in the present study, but it was observed in 15 hands (33.3% of cases). Next commonest type of complete arch was type B in 14 (31.1%), where ulnar artery alone forms the arch.

Superficial palmar arch formed by the ulnar artery alone reaching the space between the thumb and index finger was the main findings as reported by Loukas M et al., (90%) and Bilge O et al., (86%) [2,12]. Even in the present study type B superficial palmar arch (31.1%) was second most common type of variation found in complete arch after radio-ulnar (type A) type (44.5%). This classification does not correlate with Fazan VP et al., Ruengsakulrach P et al., and Lippert H and Pabst R as they classified the superficial palmar arch formed completely by ulnar artery alone as incomplete arch [13,18,22].

In case of bifurcation of superficial palmar arch or presence of arterial arcade in the superficial palmar arch, if there is bleeding from any of inter digital branches of ulnar artery the surgeon may ligate the ulnar artery above the proximal superficial palmar arch or the ulnar artery expecting the blood supply to the fourth, third and second inter digital artery to be stopped but because of complete distal superficial palmar arch or arterial arcade, bleeding may continue. So, surgeons should be careful and aware of such type of rare variation of bifurcation of superficial palmar arch and superficial palmar arch with an arterial arcade. In cases of bridging the gap to repair the cut common digital artery, the superficial palmar arch is transferred distally to the common digital artery for revascularisation of the digits [23]. The superficial palmar arch is connected directly to the digital arteries of the thumb and digital vein from the index finger were used to revascularise the thumb when there is damage to the arteria princeps pollicis [24]. Sometimes superficial palmar branch of radial artery is used in replantation of thumb [25].

The knowledge of formation and variations of superficial palmar arch should be kept in mind during fasciectomy and fasciotomy in Dupuytren's contracture repair, otherwise damage to the branches forming the arch results in haematoma [26].

Another finding in the present study was tortuous ulnar artery in 19 specimens. Tortuous artery is associated with hypertension, aging, atherosclerosis and other pathological changes in the arteries [27]. Artery Tortuosity Syndrome (ATS) is a rare condition caused by an autosomal recessive inheritance and characterised by tortuosity, elongation and aneurysm formation in major arteries due to the disruption of elastic fibres in the tunica media of the arterial wall [28]. One of the complications of tortuous ulnar artery is Guyon's canal syndrome [29,30].

When compared to other studies by Joshi SB et al., Madhyastha S et al., and Patnaik VVG et al., [3,10,19] we got both type A and type B almost in the same proportions similar to the results of Coleman SS and Anson BJ and Tagil SM et al., [6,31]. The [Table/Fig-13] shows table comparing results with previous studies [2-6,17,31-35].

Authors	Number of specimens	Complete arch	Incomplete arch
Coleman SS and Anson BJ [6] (1961)	650	78.5%	21.5%
Jaschtschinski SN [4] (1987)	200	68%	32%
Ikeda et al., [17] (1988)	220	96.4%	3.6%
Gellman H et al., [5] (2001)	45	84.5%	15.5%
Loukas M et al., [2] (2005)	200	90%	10%

Tagil SM et al., [31] (2007)	20	75%	25%
Joshi SB et al., [3] (2014)	100	82%	18%
Jena S et al., [32] (2017)	92	95.2%	4.8%
Arrchana S et al., [33] (2018)	40	72.5%	27.5%
Gnanasekaran D and Veeramani R, [34] (2019)	55	80%	20%
Dawani P et al., [35] (2020)	30	96.7%	3.3%
Present study (2020)	45	80%	20%

[Table/Fig-13]: Comparison of present study results with previous studies [2-6,17,31-35].

The presence of loops and tortuosity may result in failure to achieve coronary artery cannulation when ulnar artery is used instead of radial artery for cardiac catheterisation and it is vulnerable to get punctured or perforated during interventional procedures [36].

Limitation(s)

This study is reporting variations in a small set of population (small sample size) and only documented few variations in the anatomy of superficial palmar arch.

CONCLUSION(S)

It was found that ulnar artery is the main artery forming the superficial palmar arch and variations of patterns are caused by branches of radial artery like first dorsal metacarpal, from deep palmar arch and the median artery. The superficial palmar arch and its digital branches supply medial 3 1/2 digits normally but can supply more or less than this depending on the pattern of superficial palmar arch formation. Wounds of the palm bleed profusely but heal rapidly because of rich arterial supply. This is the basis for most of the successful reconstructive plastic surgeries of hand.

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