Chapter

Bone Graft in the Treatment of the Non-Consolidation of the Scaphoid with Necrosis of the Proximal Pole – A Systematic Review

Antônio Lourenço Severo, Osvandre Lech, Paulo Cesar Faiad Piluski, Marcelo Barreto Lemos, Carlos Castillo, Danilo Barreto Filho, Daniel Paulo Strack and Ivânio Tagliari

Abstract

The scaphoid fractures are the most common of the carpal bones, corresponding to 60; 10% of these progress to nonconsolidation, moreover, 3% can present necrosis of the proximal pole. There are various methods of treatment using vascularized (VBG) and nonvascularised bone grafts (NVBG). To evaluate and compare the rate of scaphoid consolidation with necrosis of the proximal pole using different surgical techniques. The authors conducted a systematic review of the literature using the following databases: PubMed and Bireme/Lilacs, where 13 case series were selected (10 with use of VBG and 3 of NVBG), according to inclusion and exclusion criteria. In most cases the vascularized bone grafts were used, especially those based on intercompartmental supraretinacular artery 1 and 2 due to greater reproducibility in performing the surgical technique.

Keywords: scaphoid, bone graft, scaphoid fractures, carpal bones, vascularized bone grafts, nonvascularised bone grafts

1. Introduction

The scaphoid fractures are the most common of the carpal bones, corresponding to 60% of these fractures. In spite of the existing consolidation without surgical treatment, some series of cases indicate rates of nonconsolidation of up to 10% [1]. Recent data suggest that the major risk factor for the nonconsolidation is the displacement of the fragments, which is associated with nonconsolidation rates of up to 55% [2].

Avascular necrosis has an estimate of occurrence of 3% in all cases of scaphoid fractures and occurs predominantly in the proximal pole, which has been attributed to the peculiarity of vascularization of this bone; studies on this subject describe that the arterial supply of the scaphoid occurs through three vessels (volar side, dorsal and distal) named according to spatial relationship with the scaphoid [3–5].

More recently some studies showed that there are two arteries: one fully dorsal and another limited to the tubercle [6].

For the diagnosis of avascular necrosis the use of magnetic resonance imaging (MRI) has been recommended, which has an accuracy of up to 68%, increasing to 83% when associated with the use of gadolinium contrast. However, the gold standard is the intraoperative assessment of the absence of bleeding in the proximal fragment [7].

Several treatment techniques have been described using bone grafts, both vascularized (VBG) and nonvascularized bone grafts (NVBG). The use of nonvascularized bone grafts began with Adams and Leonard in 1928, who used cortical graft of the tibia embedded in the proximal and distal fragment through the back access via [8].

In 1934, Murray [9] described the embedded tibial graft usage through the tuberosity of the scaphoid; Bernard and Stubins in 1928 described the withdrawal of this bone pin from styloid process of the radius [10].

Matti in 1936 developed the technique in which an excavation in the proximal and distal scaphoid fragments was performed through the dorsal via, and that was later filled with cancellous bone graft [11]. Russi in 1960 modified Matti's technique using the volar via to preserve the vascularization of the scaphoid, performing niche filling with cancellous bone graft in a single block [12].

In 1970, Fisk observed the intense reabsorption of the volar portion of the fragments and the instability that follows, where distal fragment tends to flexion and the proximal fragment tends to stretch together with the semilunate, and later proposing the use of cortical cancellous graft correcting this deformity [13]. Later, Segmüller in 1973 [14] followed the precepts described by Fisk, but described the association of the use of osteosynthesis material (traction screw). Consequently, Fernandez, in 1984, described this technique in detail [15].

In 1965, Roy-Camille [16] published the technique of the VBG taken from the tuberosity of the scaphoid. Later, in 1986, Kuhlmann described the technique in which VBG removed from the medial portion and the volar portion of the distal radius were used for treatment of failures occurring after use of Matti-Russe technique [17].

In [18], work describing the vascularized graft taken from the distal portion of the radius with the vascularization based of intercompartmental supraretinacular artery 1 and 2 (1,2 ICSRA) was published.

In a recent systematic review [19], it was concluded that the consolidation rate of scaphoid fracture that evolved to a nonconsolidation with use in vascularized bone graft was of 88 versus 47% with use of nonvascularized graft.

In face of these data, this study aimed to carry out an updated literature review about the consolidation rates with use of different types of grafts (vascularized and nonvascularized) used for the treatment of scaphoid nonunion with necrosis of the proximal pole.

2. Methodology

A search was conducted in the current medical literature, by searching in the databases PubMed and Bireme/Lilacs using combinations of keywords below [20] (**Table 1**):

1. Bone graft scaphoid
2. Nonunion scaphoid
3. Vascularized bone graft nonunion scaphoid
4. Cancellous bone graft scaphoid
5. Pseudoarthrosis scaphoid

Term used on the search	Number of articles on PubMed	Articles selected from PubMed	Number of articles on Bireme	Articles selected from Bireme
Bone graft scaphoid	267	22	167	24
Nonunion scaphoid	273	19	182	18
Vascularized bone graft nonunion scaphoid	22	20	34	16
Structural bone graft nonunion scaphoid	10	8	6	5
Pseudoarthrosis scaphoid	66	10	273	13

Table 1.
Search in the current medical literature through the PubMed and Bireme/Lilacs data base.

All articles that made no reference to the use of bone graft to the treatment of nonunion of the scaphoid were excluded, which made reference to the use of graft in skeletally immature individuals, citing the use of bone grafts in other pathologies of the carpus and published articles for more than 20 years.

Thus the following selection was obtained.

Within the selected articles any work that made no reference to the occurrence of avascular necrosis of the proximal pole were excluded.

Therefore, a total of 13 articles were used for the analysis of the results.

3. Analysis of results

After the literature review, it can be seen that in the last two decades there is a tendency to the preference for the use of vascularized bone grafts in cases of non-consolidation of the scaphoid, especially when there are signs of avascular necrosis of the proximal pole, the main indication for the use of these grafts.

A systematic review of the literature highlights the use of various techniques of vascularized bone grafts (VBG), including: VBG based on capsular circulation, VBG based on metaphyseal circulation of the distal radius, VBG based on the volar circulation of the distal radius, based on the VBG supraretinacular artery between the 1st and 2nd extensor compartment (1,2 ICSRA), VBG coming from femoral condyle and coming from the iliac crest; the latter achieved using microanastomosis in the radial artery. All techniques show high consolidation rates, with an average of 89% (**Table 2**).

Steinmann et al. [21] in his work, made use of the distal radius graft with 1,2 ICSRA technique described by Zaindenberg; reached consolidation rates of 100% in 44 cases treated with this technique. Of these, eight had necrosis of the proximal pole. Tsai et al. [22] also by use of the technique 1,2 ICRSA reached consolidation rate of 80% (4 of 5 patients). Liang et al. [23] using the same technique described above had consolidation rates of 100%. However, unlike the previous work, [24] also used the vascularized bone graft technique based on 1,2 ICRSA, reaching consolidation rates of 100% in 10 patients, 5 cases with necrosis of the proximal pole of the scaphoid (**Tables 2** and **4**).

However, the study done by [25] in which vascularized bone graft based on 1,2 ICSRA was also used, shows consolidation rates well below comparing to the studies cited above. This work achieved consolidation rates of only 27% in 22 cases of nonconsolidation of the scaphoid and if only the cases with signs of necrosis of the proximal pole are considered, this percentage decreases to 12.5% (**Tables 2** and **4**).

Steinmann et al. [21] describe high rates of consolidation using distal radio bone graft based on capsular circulation, reaching 80% of consolidation, 10 cases were evaluated

Author	Consolidation rate	Kind of vascularized graft
[21]	100%	VBG based on 1,2 ICSRA
[22]	80%	VBG based on 1,2 ICSRA
[23]	100%	VBG based on 1,2 ICSRA
[24]	100%	VBG based on 1,2 ICSRA
[25]	27%	VBG based on 1,2 ICSRA
[26]	80%	VBG based on capsulate circulation
[27]	87%	VBG based on the first metacarpal artery
[28]	89%	VBG based on 1,2 ICSRA
[29]	73%	VBG based on the anterior transverse carpal artery
[30]	100% 40%	VBG from the femural condyle 1,2 ICRA

Vascularized bone graft (VBG), supraretinacular artery between compartments 1 and 2 [1,2 ICSRA].

Table 2.
Consolidation rates according to the technique used to the use of vascularized bone graft.

where all had necrosis of the proximal pole. The authors highlight the lack of need for dissection of small vessels as a great advantage of this technique (**Tables 2** and **4**).

Using the bone graft taken from the base of the thumb with the vascularization based on the first metacarpal artery, [27] have reached the consolidation rate of 87% in the series of 24 patients. In this work, four cases with necrosis of the proximal pole were included and all obtained radiographic consolidation. Despite the need for dissection of a small vessel, the authors report as an advantage the constancy in all cases of the first metacarpal artery (**Tables 2** and **4**).

In the study of [28] they realized the prospective evaluation of 46 patients who were treated with the use of vascularized bone graft based on 1,2 ICSRSA versus 40 patients treated with the use of nonvascularized bone graft taken from the distal radius and they obtained a statistically significant result in favor of the use of vascularized bone graft with a rate of 89.1 versus 72.5% with use of nonvascularized graft. Within the group of patients who underwent VBG use, 21 presented necrosis of the proximal pole and of these 19 have achieved consolidation (90.5%) (**Tables 2** and **4**).

In the study of [29] using VBG of the volar portion of the distal radius based in the anterior transverse carpal artery, 73% of consolidation rates were obtained in 30 cases. In this series two cases had signs of avascular necrosis of the proximal pole and neither obtained consolidation with the proposed treatment (**Tables 2** and **4**).

In their study, [30] compared consolidation rates into two groups treated with VBG: in a group of 22 patients they used graft taken from the distal radius with circulation based on 1,2 ICSRA and another group with 12 patients they used bone graft free from the femoral condyle. They achieved a statistically superior results using graft derived from the femoral condyle which reached the rate of 100 versus 40% of consolidation with graft originated from the distal radius (**Tables 2** and **4**).

Regarding the techniques that describe the use of NVBG for the treatment of nonunion of the scaphoid with necrosis of the proximal pole, only three series of case were found in this study that did not have the defined exclusion criteria. Matsuki et al. [31] proposed an investigation to assess the rate of consolidation of the proximal pole of the scaphoid fractures using NVBG associated with the fastening with Herbert bone screws; where 11 patients were evaluated and obtained consolidation in all of them (**Tables 3** and **4**). Using the same technique, [32] investigated 17 patients with 1 year follow up and obtained a consolidation rate of 52% (**Tables 3** and **4**). Ribak et al. [28] carried out the research on the consolidation rate

Author	Consolidation rate	Kind of nonvascularized graft
[31]	100%	Corticocancellous bone graft of the iliac crest
[32]	52%	Corticocancellous bone graft of the iliac crest
[28]	72%	Corticocancellous bone graft of the distal radius.

Table 3.
Consolidation rate according to the technique used for use of nonvascularized bone graft.

Author	NPP cases	Consolidation rates	Kind of graft
[21]	8	100% (8/8)	VBG based on 1,2 ICSRA
[22]	5	80% (4/5)	VBG based on 1,2 ICSRA
[23]	11	100% (11/11)	VBG based on 1,2 ICSRA
[24]	5	100% (5/5)	VBG based on 1,2 ICSRA
[25]	16	12,5% (2/16)	VBG based on 1,2 ICSRA
[26]	10	80% (8/10)	VBG based on capsular circulation EOV baseado na circulação capsular
[27]	4	100% (4/4)	VBG based on the first metacarpal artery EOV baseado na 1ª artéria metacarpal
[28]	21	19/21 (90.5%)	1,2 ICRA
[29]	2	0/2 (0%)	VBG based on the anterior transverse carpal artery exclusion of all in Portuguese that are in the table
[30]	10 12	4/10 (40%) 12/12 (100%)	1,2 ICRA VBG from the femural condyle
[31]	11	11/11 (100%)	Corticocancellous bone graft of the iliac crest Enxerto ósseo cortico esponjoso da crista ilíaca
[32]	17	52% (9/17)	Corticocancellous bone graft of the iliac crest Enxerto ósseo cortico esponjoso da crista ilíaca
[28]	16	68% (11/16)	Corticocancellous bone graft of the distal radius Enxerto ósseo cortico esponjoso do rádio distal

Table 4.
Consolidation rates, considering only cases with necrosis of the proximal pole of the scaphoid (NPP), vascularized bone graft (VBG), supraretinacular artery between compartments 1 and 2 [1,2 ICSRA].

with use of NVBG in 40 patients; of these, 16 presented necrosis of the proximal pole and the consolidation was achieved in 11 of them (**Tables 3** and **4**).

4. Discussion

The evidence supports that the arterial supply of the proximal pole is poor in comparison to the two-thirds of the distal scaphoid. The proximal pole for being entirely intraarticular is covered with hyaline cartilage with only one ligament insertion (radioscaphoid-lunate ligament). So its vascularization is entirely dependent on intraosseous circulation. Thus, when there is loss of continuity solution due to deviation fracture, this circulation is impaired favoring the occurrence of non-consolidation [33, 34].

Tsai et al. [22] cites two basic reasons for the preference for the use of vascularized bone graft (VBG) regarding the use of vascularized bone graft not (NVBG): the shorter consolidation time, which implies a faster functional recovery, and ability to carry blood supply to a nonvascularized bone.

Since the publication of [18], who obtained 100% of consolidation in cases of nonconsolidation of the scaphoid, there is a growing interest in indicating the use

of VBG based on the circulation of the dorsal radius, particularly with the use of the extensor intercompartmental supraretinacular artery between 1 and 2 [1,2 ICSRA]. Supporting this data in a recent publication, [19] published a meta-analysis study which showed a consolidation rate of 88 versus 47% using VBG and NVBG, respectively. The 1,2 ICRSA runs superficially on the retinaculum of the extentions and heads distally to the radial metaphyseal bone. According to the studies using this technique, easy identification and dissection of the artery are the major advantages. This came accordingly to the work of [35], which showed a consolidation rate of 93% using the technique described by Zaidenberg.

In [21, 23, 24], the 1,2 ICRSA technique was also used in their work, all reaching a consolidation rate of 100%. The three authors consider this a technically easier procedure, compared with other VBG techniques, also for being limited to only one incision. In addition, the correction DISI (dorsal intercalated segment instability) was obtained, caused by the curvature of the humpback scaphoid, a factor that helps increasing the range of motion postoperatively. Opposed to these studies, [7], the restoration of carpal geometry is essential for the consolidation, however the techniques that use bone graft derived from the distal radius, would provide a too small bone graft for humpback correction, i.e., the DISI. Thus, a means of achieving VBG that met this condition was the use of bone graft originated from the medial femoral condyle. The disadvantage of this technique would be the need of microsurgical technique usage for small vessel anastomosis, on the other hand, a graft with excellent quality would be obtained, that would offer greater rigidity when compared to graft taken from the distal radius. However, it should be noted that the technique that uses graft free from the femoral condyle requires microsurgical technique mastery, requiring specific training and long learning curve [30].

Jones et al. [30] compared two groups: VBG from the femoral condyle based on the VBG versus 1,2 ICSRA with consolidation rates of 100 and 40%, respectively. Ribak et al. [28] obtained consolidation of 89% using VBG based on 1,2 ICSRA versus consolidation of 72% using NVBG obtained from the distal radius. But for [25] using the VBG based on the 1,2 ICSRA concluded that this technique was ineffective in the series, with consolidation rates of 27% and reducing to 12.5% if we consider only cases of necrosis of the proximal pole.

Bertelli et al. [27] observed consolidation rates in 21 of 24 patients using the VBG based on the first metacarpal artery. These authors prefer to use of VBG due to the greater effectiveness in promoting bone consolidation compared to nonvascularized bone grafts, even in difficult situations such as avascular necrosis of the proximal pole.

The use of VBG using the capsular movement of the distal radius was described by [26] in which obtained consolidation rates of 80%. For these authors, this is a relatively simple technique that eliminates the need for dissection of small vessels or microanastomoses, and lead to a lower risk of vascular injury. A limitation of this technique, however, lies in failing to correct the humpback scaphoid deformity.

Jessu et al. [29] used VBG based on the anterior transverse carpal artery, i.e., vascularized bone grafts proposed by [34], obtained consolidation rate of 73% in 30 patients with nonunion of the scaphoid, however the two cases of proximal pole necrosis were not consolidated. The authors considered the consolidation rate disappointing, but still consider this to be an advantageous technique, mainly for its unique volar approach that reduces morbidity, but its realization requires long learning curve.

All the studies that use the 1,2 ICSRA technique highlight the easy viewing and dissection of the pedicle, which make this technique extremely useful for the treatment of nonunion of the scaphoid with necrosis of the proximal pole [21–25, 28].

The studies that use NVBG, basically used cortical cancellous bone grafts, simple techniques that have as an advantage the easy material removal. But there was an important change in consolidation rates, where [31] achieved great overall

results, amounting to consolidation of 100% in 11 patients with necrosis of the proximal pole of the scaphoid. [28, 32], on the other hand, reached a much lower rate of 72 and 55%, respectively.

5. Conclusion

There is preference for the use of vascularized bone graft in relation to non-vascularized bone grafts, although the surgical technique is more detailed and demanding specific training, mainly in cases requiring vascular microsurgery, works using the technique for vascularized bone grafts reflect a better reproduction of positive results compared to conventional bone grafts. Therefore, according to this systematic review, there is no consensus in the literature that the use of vascularized bone graft can be effective in all cases for scaphoid consolidation with necrosis of the proximal pole.

Author details

Antônio Lourenço Severo[1*], Osvandre Lech[2], Paulo Cesar Faiad Piluski[2], Marcelo Barreto Lemos[3], Carlos Castillo[2], Danilo Barreto Filho[4], Daniel Paulo Strack[5,6] and Ivânio Tagliari[7]

1 Hand Surgery and Microsurgery of Univ. Federal Fronteira Sul (UFFS), Hospital São Vicente de Paulo (HSVP), Instituto Ortopedia e Traumatologia (IOT), Passo Fundo, RS, Brazil

2 UFFS, HSVP, IOT Shoulder and Elbow Surgery Department, Passo Fundo, RS, Brazil

3 UFFS, HSVP, IOT Hand Surgery and Microsurgery Department, Passo Fundo, RS, Brazil

4 Hand Surgery Department at MIguel Riet Correa Jr. FURG-EBSERH University Hospital

5 Orthopedics and Traumatology Department Center, IJUÍ, RS, Brazil

6 Unimed Noroeste

7 UPF Graduate Program in Projects and Manufacturing Processes, HSVP Research Center/Unit 02, IOTRS, Passo Fundo, RS, Brazil

*Address all correspondence to: antoniolsevero@gmail.com

References

[1] Geert A, Buijze LO, Ring D. Management of scaphoid nonunion. Journal of Hand Surgery. 2012;**37A**:1095-1100

[2] Talal A-J, Mannan A, Giannoudis P. The use of the free vascularised bone graft for nonunion of the scaphoid: A systematic review. Journal of Orthopaedic Surgery and Research. 2014;**9**:21

[3] Grettve S. Arterial anatomy of the carpal bones. Acta Anatomica. 1955;**25**:331

[4] Minne J, Depreux R, Mestdagh H. Les pédicules artérieles du massif carpien. Lille Médical. 1973;**18**:1174

[5] Taleisnik J, Kelly PJ. The extraosseous and intraosseous blood supply of the scaphoid bone. The Journal of Bone and Joint Surgery. American Volume. 1966;**48**:1125-1137

[6] Gelberman RH, Menon J. The vascularity of the scaphoid bone. Journal of Hand Surgery. 1980;**5**:508-513

[7] Sanjeev K, Bishop AT, Shin A. Role of vascularized bone grafts in the treatment of scaphoid nonunions associated with proximal pole avascular necrosis and carpal collapse. Journal of Hand Surgery. 2011;**36**:722-725

[8] Adams JD, Leonard RD. Fracture of the carpal scaphoid a new method of treatment with a report of one case. NEJM. 1928;**198**(8):401-404

[9] Murray J. Bone graft for non union of the carpal scaphoid. British Journal of Surgery. 1934;**22**:63-68

[10] Bernard L, Leonard RD. Fracture of the carpal scaphoid: A new method of treatment with a report of one case. NEJM. 1928;**198**(8):401-404

[11] Matti H. Technik und resultate meiner pseudarthosenoperation. Zentralblatt für Chirurgie. 1936;**63**:1442-1453

[12] Russe O. Fracture of navicular carpal: Diagnosis, non operative and operative treatment. JBJS. 1960;**42A**(5):759-768

[13] Fisk GR. Carpal instability and the fractured scaphoid. Annals of the Royal College of Surgeons of England. 1970;**46**:63-76

[14] Segmüller G. Navikulare-pseudarthrose. In: Operative Stabilisierung am Handskelet. Bern: Verlag Hans Huber; 1973. pp. 99-104

[15] Fernandez DL. A technique for anterior wedge-sheped grafts for scaphoid non-union with carpal instability. The Journal of Hand Surgery. 1984;**9**:733-737

[16] Roy-Camille R, Fractures ET pseudarthroses D. Scaphoid moyen utilisation d'um gref for pedicule. Actual Chir Orthop Raymond Poincare. 1965;**4**:197-214

[17] Trumble TE, Vo D. Proximal pole scaphoid fractures and nonunion. Journal of the American Society for Surgery of the Hand. 2001;**3**:155-171

[18] Zaidenberg C, Siebert JW, Angrigiani C. A new vascularized boné graft for scaphoid nonunion. The Journal of Hand Surgery. 1991;**16**(A):474-478

[19] Merrel GA, Wolfe S, Slade JF. Treatment of scaphoid nonunions: Quantitative meta-analysis of the literature. Journal of Hand Surgery. 2003;**27**:685-691

[20] Kelly AL, Gerad PS. Understanding systematic reviews and meta-analyses in orthopaedics. Journal of the American Academy of Orthopaedic Surgeons. 2013;**21**:0245-0255

[21] Steinmann SP, Bishop AT, Berger RA. Use of the 1,2 intercompartmental supraretinacular artery as vascularized pedicle bone graft for difficult scaphoid nonunion. The Journal of Hand Surgery. 2002;**27a**:391-401

[22] Tsai TT, Chao EK, Tu YK, Chen AC, Lee MS, Ueng SW. Management of scaphoid nonunion with avascular necrosis using 1,2intercompartmental supraretinacular arterial bone grafts. Chang Gung Medical Journal. 2002;**25**:321-328

[23] Liang K, Ke Z, Chen L, Nie M, Cheng Y, Deng Z. Scaphoid nonunion reconstructed with vascularized bone-grafting pedicled on 1,2 intercompartmental supraretin-acularartery and external fixation. European Review for Medical and Pharmacological Sciences. 2013;**17**:1447-1454

[24] Uerpairojkit C, Leechavengvongs S, Witoonchart K. Primary vascularized distal radius bone graft for nonunion of the scaphoid. Journal of Hand Surgery. 2000;**25b**(3):266-22470

[25] Straw RG, Davis TRC, Dias JJ. Scaphoid nonunion: Treatment with a pedicledvascularized bone graft based on the 1,2 intercompartmental supraretinacularbranch of the radial artery. Journal of Hand Surgery. 2002;**27b**(5):413-416

[26] Sotereanos DG, Nickolaos AD, Dailiana ZH, Sarris IK, Konstantinos NM. A capsular-based vascularized distal radius graft for proximal pole scaphoid pseudarthrosis. Journal of Hand Surgery. 2006;**31a**:580-587

[27] Bertelli JA, Tacca CP, Rost J. Thumb metacarpal vascularized bone graft in long-standing scaphoid nonunion—A useful graft ,via dorsal or palmar approach: A cohort study of 24 patients. Journal of Hand Surgery. 2004;**29a**:1089-1097

[28] Ribak S, Medina CEG, Mattar R, Ulson HJR, Resende MR, Etchebehere M. Treatment of scaphoid nonunion with vascularised and nonvascularised dorsal bone grafting from the distal radius. International Orthopaedics. 2010;**34**:683-688

[29] Jessu MA, Wavreille GB, Strouk C, Fontaine BC. Chantelot b.scaphoid nonunions treated by kuhlmann's vascularized bone graft: Radiographic outcomes and complications. Chirurgie de la Main. 2008;**27**:87-96

[30] Jones DB Jr, Burger H, Bishop AT, Shin AY. Treatment of scaphoi waist nonunion with na avascular proximal pole and carpal colapse: A comparisson of two vascularized boné grafts. The Journal of Bone and Joint Surgery. American Volume. 2008;**90**:2616-2625

[31] Matsuki H, Junichi I, Iwasaki N, Uchiyama S, Minami A, Kato H. Non-vascularized bone graft with Herbert-type screw fixation for proximal pole scaphoid nonunion. Journal of Orthopaedic Science. 2011;**16**:749-755

[32] Randall RR, Ridge O, Carter PR. Iliac crest bone grafting and Herbert screw fixation of nonunions of the scaphoid with avascular proximal poles. Journal of Hand Surgery. 1995;**20A**:818-831

[33] Geissler WB, Slade JF. Fractures of the carpal bones. In: Green DP. Green's Operative Hand Surgery. 6th ed. Vol. 1. Elsevier Churchill Living Stone; 2010. p. 639-707

[34] Caporrino FA, Faloppa F, Dos Santos JBG, et al. Tratamento Cirurgico da Não consolidação do Escafóide com enxerto vascularizado da extremidade dorsal e distal do radio, baseado na artéria supraretinacular

1,2. Revista Brasileira de Ortopedia. 2003;**38**(9):522-533

[35] Kuhlmann JN, Mimoum M, Boabighi A, Baux S. Vascularized bone graft pedicled on the volar carpal artery for non-union of the scaphoid. Journal of Hand Surgery (British). 1987;**12**(2):203-210