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Bone graft in the treatment of nonunion of the scaphoid with necrosis of the proximal pole: a literature review[☆]



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ABSTRACT

Scaphoid fractures are the most common fractures of the carpal bones, corresponding to 60%. Of these, 10% progress to nonunion; moreover, 3% can present necrosis of the proximal pole. There are various methods of treatment using vascularized and non-vascularized bone grafts.

To evaluate and compare the rate of scaphoid consolidation with necrosis of the proximal pole using different surgical techniques.

The authors conducted a review of the literature using the following databases: PubMed and BIREME/LILACS, where 13 case series were selected (ten with use of vascularized bone grafts and three of non-vascularized bone grafts), according to inclusion and exclusion criteria.

In most cases VBGs were used, especially those based on the 1,2 intercompartmental supraretinacular artery, due to greater reproducibility in performing the surgical technique.

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Enxerto ósseo no tratamento da não consolidação do escafoide com necrose do polo proximal: revisão da literatura

RESUMO

As fraturas do escafoide são as mais comuns dos ossos do carpo, correspondem a 60%. Dessas, 10% evoluem para não consolidação; além disso, 3% podem apresentar necrose do polo proximal. Existem vários métodos de tratamento com enxertos ósseos, vascularizados e não vascularizados.

Palavras-chave:

Ossos escafoide

Osteonecrose

Fraturas não consolidadas

Transplante ósseo

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Avaliar e comparar as taxas de consolidação do escafoide com necrose do polo proximal com diferentes técnicas cirúrgicas.

Fez-se uma revisão na literatura nas bases de dados PubMed e Bireme/Lilacs, das quais foram selecionadas 13 séries de casos (dez com uso de enxertos ósseos vascularizados e três enxertos ósseos não vascularizados), de acordo com os critérios de inclusão e exclusão.

Enxertos ósseos vascularizados foram usados na maioria dos casos, principalmente naqueles baseados na artéria intercompartmental suprarretinacular 1 e 2, devido à maior reprodutibilidade na técnica cirúrgica.

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Introduction

Scaphoid fractures are most common fractures of the carpal bones, accounting for 60% of such fractures. Although consolidation can occur without the need for surgical treatment, some case series indicate nonunion rates of up to 10%.¹ Recent data suggest that the main risk factor for nonunion is fragment dislocation, which is associated with nonunion rates of up to 55%.²

Avascular necrosis has an estimated occurrence of 3% in all cases of scaphoid fractures; it occurs predominantly in the proximal pole, a fact attributed to the peculiar vascularization of this bone. Studies on the subject describe that the arterial supply of the scaphoid flows through three vessels (lateral volar, dorsal and distal), classified according to their spatial relation with the scaphoid.^{3,4} More recently, some studies have shown the existence of two arteries: one completely dorsal and the second limited to the tubercle.⁵

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 an intraoperative evaluation of the absence of bleeding in the proximal fragment.⁶ Several treatment techniques have been described, with both vascularized (VBG) and non-vascularized (NVBG) bone grafts.

In a recent systematic review, Merrel et al.⁷ concluded that the rate of consolidation of scaphoid fractures that evolved to nonunion was 88% in VBG vs. 47% in NVBG. In light of such data, this study aimed to perform an updated literature review on the rates of consolidation using the different types of grafts (VBG and NVBG) used for the treatment of nonunion of the scaphoid with necrosis of the proximal pole.

Methods

The current medical literature in the PubMed and BIREME/LILACS databases was searched using the following keyword combinations (Table 1)⁸:

1. Bone graft scaphoid
2. Non union scaphoid
3. Vascularized bone graft non union scaphoid
4. Cancellous bone graft scaphoid

5. Pseudoarthrosis scaphoid

All articles that did not mention the use of bone grafts for the treatment of nonunion of the scaphoid, those that referred the use of immature skeletal graft, those that cited the use of bone grafts in other carpal pathologies, and those published over 20 years were excluded.

Thus, the following selection was obtained (Table 1).

All the articles that did not refer to avascular necrosis of the proximal pole were excluded.

Therefore, 13 articles were included.

Analysis of results

After a literature review, it was observed that in the last two decades there has been a tendency toward the use of VBG in cases of nonunion of the scaphoid, especially when there are signs of avascular necrosis of the proximal pole, the main indication for the use of these grafts.

The literature review evidenced the use of several VBG techniques, among them: VBG based on capsular circulation, VBG based on the metaphyseal circulation of the distal radius, VBG based on the volar circulation of the distal radius, VBG based on the 1,2 intercompartmental suprarretinacular artery (1,2 ICSRA), and VBG originating from the femoral condyle and from the iliac crest (the latter made through microanastomosis on the radial artery). All techniques show high consolidation rates, with a mean of 89% (Table 2).

Steimann et al.⁹ used the distal radius graft with the 1,2 ICSRA technique described by Zaindenberg; these authors achieved a consolidation rate of 100% in 44 cases treated with this technique. Of these, eight had proximal pole necrosis. Tsai et al.¹⁰ also using the 1,2 ICSRA technique, achieved consolidation rates of 80% (four out of five patients). Liang et al.¹¹ used the same technique as described above, obtaining a consolidation rate of 100%. Uerpaiojkit et al.¹² also used the vascular graft technique based on the 1,2 ICSRA and achieved a consolidation rate of 100% in ten treated patients, five with necrosis of the proximal pole of the scaphoid (Table 2).

However, the study developed by Straw et al.,¹³ in which a vascularized bone graft was also used based on the 1,2 ICSRA, presented consolidation rates well below those previously mentioned. That study obtained consolidation rates of only 27% in 22 cases of nonunion of the scaphoid; when

Table 1 – Search in current medical literature through the PubMed and BIREME/LILACS databases.

Term used in research	Number of articles in PubMed	Selected PubMed articles	Number of articles in BIREME	Selected BIREME articles
Bone graft scaphoid	267	22	167	24
Non union scaphoid	273	19	182	18
Vascularized bone graft non union scaphoid	22	20	34	16
Structural bone graft non union scaphoid	10	8	6	5
Pseudoarthrosis scaphoid	66	10	273	13

Table 2 – Consolidation rate according to the technique used for vascularized bone grafting. Vascularized bone graft (VBG), 1,2 intercompartmental supraretinacular artery (1,2 ICSRA).

Author	Consolidation rate	Type of vascularized graft	Consolidation rate considering the cases of proximal pole necrosis (PPN)
Steinmann et al. ²² (2002)	100%	VBG based on 1,2 ICSRA	100% (8/8)
Tsai et al. ²¹ (2002)	80%	VBG based on 1,2 ICSRA	80% (4/5)
Liang et al. ²² (2013)	100%	VBG based on 1,2 ICSRA	100% (11/11)
Uerpaiojkit et al. ²³ (2000)	100%	VBG based on 1,2 ICSRA	100% (5/5)
Straw et al. ²⁴ (2002)	27%	VBG based on 1,2 ICSRA	12.5% (2/16)
Sotereanos et al. ²⁵ (2006)	80%	VBG based on 1,2 ICSRA	80% (8/10)
Bertelli et al. ²⁶ (2004)	87%	VBG based on the first metacarpal artery	100% (4/4)
Ribak et al. ²⁷ (2002)	89%	VBG based on 1,2 ICSRA	90.5% (19/21)
Jessu et al. ²⁸ (2008)	73%	VBG based on the anterior transverse carpal artery	0% (0/2)
Jones et al. ²⁸ (2008)	100%, 40%	VBG obtained from the femoral condyle VBG based on 1,2 ICSRA	40% (4/10), 100% (12/12)

assessing only cases with signs of proximal pole necrosis, this percentage decreased to 12.5% (Table 2).

Sotereanos et al.¹⁴ described high consolidation rates (80%) with distal radius bone graft based on capsular circulation; ten cases were evaluated, all of which had proximal pole necrosis. The authors emphasize the absence of small vessel dissection as a great advantage of this technique (Table 2).

Removing the bone graft from the base of the thumb and using a vascularization technique based on the first metacarpal artery, Bertelli et al.¹⁵ reached a consolidation rate of 87% in a series of 24 patients. Four cases with proximal pole necrosis were included in that study, and radiographic consolidation was achieved in all of them. Despite the need to dissect a small vessel, the authors report as an advantage the presence, in all cases, of the first metacarpal artery (Table 2).

In the study by Ribak et al.,¹⁶ a prospective evaluation of 46 patients treated with VBG based on the 1,2 ICSRA vs. 40 patients treated with an NVBG extracted from the distal radius, the authors observed a statistically significant result in favor of the use of a VBG, with a rate of 89.1% vs. 72.5% in those treated with NVBG. Within the group of patients in whom VBG was used, 21 had proximal pole necrosis; of these, consolidation was achieved in 19 (90.5%; Table 2).

In the study by Jessu et al.¹⁷ with VBG of the volar portion of the distal radius based on the anterior transverse carpal artery, a consolidation rate of 73% was obtained in 30 cases. In that series, two cases had signs of avascular necrosis of the proximal pole, and none presented consolidation with the proposed treatment (Table 2).

In their study, Jones et al.¹⁸ compared the rates of consolidation in two groups treated with VBG. In one group of 22 patients, the graft was taken from the distal radius and its vascularization was based on the 1,2 ICSRA; in the other group, with 12 patients, a free bone graft from the femoral condyle was used. A statistically superior result was obtained when the graft was obtained from the femoral condyle, which reached a consolidation rate of 100%, vs. 40% in the group in which the graft was obtained from the distal radius (Table 2).

Regarding the techniques that describe the use of NVBG for the treatment of nonunion of the scaphoid with proximal pole necrosis, only three case series were retrieved in the present study, which did not present defined exclusion criteria. Matsuki et al.¹⁹ evaluated the consolidation rate of proximal scaphoid pole fractures, in which NVBG was associated with the fixation of a Herbert screw; 11 patients were evaluated and consolidation was observed in all (Table 3). With the same technique, Robbins et al.²⁰ investigated 17 patients with a one-year follow-up and observed a consolidation rate of 52% (Table 3). Ribak et al.¹⁶ assessed the consolidation rate using NVBG in 40 patients; of these, 16 had necrosis of the proximal pole and 11 achieved consolidation (Table 3).

Discussion

Evidence supports the hypothesis that the arterial supply of the proximal pole is poor when compared with the distal two-thirds of the scaphoid. The proximal pole, being

Table 3 – Consolidation rate according to the technique used for non-vascularized bone grafting.

Author	Consolidation rate	Type of non-vascularized graft	Consolidation rate considering the cases of proximal pole necrosis (PPN)
Matsuki et al. ³⁰ (2011)	100%	Corticocancellous bone graft obtained from the iliac crest	100% (11/11)
Robbins et al. ³¹ (1995)	52%	Corticocancellous bone graft obtained from the iliac crest	52% (9/17)
Ribak et al. ²⁷ (2002)	72%	Corticocancellous bone graft obtained from the distal radius	68% (11/16)

entirely intra-articular, is covered by hyaline cartilage with only one ligament insertion, the radioscapholunate ligament. Therefore, its vascularization is completely dependent on the intraosseous circulation. Finally, when the solution of continuity is lost due to deviated fracture, this circulation is impaired, favoring nonunion.²¹

The use of NVBG began with Adams and Leonard,²² who used a cortical tibial graft embedded in the proximal and distal fragment through the dorsal access route. In 1934, Murray²³ described the use of a tibial graft pegged through the scaphoid tuberosity; in 1928, Barnard and Stubbins²⁴ described the removal of this bone peg from the styloid process of the radio.

In 1936, Matti²⁵ developed the technique in which the proximal and distal fragments of the scaphoid were excavated through a dorsal access route, creating a groove which was filled with cancellous bone graft. Russe²⁶ modified the Matti technique when using the volar access route to preserve the vascularization of the scaphoid and to fill the groove with *en bloc* cancellous graft.

In turn, Fisk²⁷ observed an intense resorption of the volar portion of the fragments and the ensuing instability, in which the distal fragment tends to flex and the proximal fragment tends to extend along with the lunate. He proposed the use of a corticocancellous graft to correct this deformity. Subsequently, Segmüller²⁸ followed the precepts described by Fisk; however, he described the association of the use of osteosynthesis material (traction screw). Nonetheless, it was Fernandez²⁹ who described this technique in detail.

In 1965, Roy-Camille³⁰ published the technique of VBG obtained from the scaphoid tuberosity. In 1986, Kuhlmann et al.³¹ described a technique in which VBG taken from the medial portion and volar from the distal radius were used to treat failures that occurred after using the Matti-Russe technique.

Zaidenberg et al.³² published an article describing the use of VBG removed from the distal portion of the radius with 1,2 ICSRA vascularization.

Tsai et al.¹⁰ mentioned two basic reasons for the preference for the use of VBG over NVBG: the shorter consolidation time, which implies faster functional recovery, and the ability to deliver blood to devascularized bone.

Since the publication of Zaidenberg et al.,³² who achieved a consolidation rate of 100% in cases of nonunion of the scaphoid, a growing interest in the indication of the use of VBG based on the dorsal circulation of the radius has been observed, particularly with the use of the 1,2 ICSRA. In support of these data, a recent meta-analysis by Merrel et al.⁷

demonstrated a consolidation rate of 88% vs. 47% with the use of VBG and NVBG, respectively. The 1,2 ICSRA runs superficially over the extensor retinaculum and distally to the radial metaphyseal bone. According to the studies that used this technique, the easy identification and dissection of the artery is its main advantage.

Steimann et al.,⁹ Liang et al.,¹¹ and Uerpairojkit et al.¹² also used the 1,2 ICSRA technique; all studies observed a consolidation rate of 100%. The authors of these three studies considered this procedure to be technically easier when compared with other VBG techniques, in addition to its single incision. Furthermore, the dorsal intercalated segment instability (DISI) caused by the scaphoid curvature (humpback) was corrected, a fact that helps to increase the arc of movement postoperatively. In contrast, in the study by Kakar et al.,⁶ the restoration of carpal geometry was essential for consolidation. However, the bone graft obtained from the distal radius would be too small for correction of humpback, i.e., DISI. Thus, to obtain a VBG that met this requirement, bone graft from the medial femoral condyle was used. The disadvantage of this method would be the need to use a microsurgical technique for small vessel anastomosis; in turn, an excellent graft would be obtained, offering greater rigidity than grafts removed from the distal radius. Nonetheless, it should be pointed out that the technique that uses the free graft of the femoral condyle requires a domain of microsurgical techniques, specific training, and a long learning curve.¹⁸

Jones et al.¹⁸ compared two groups: VBG from the femoral condyle vs. VBG based on the 1,2 ICSRA, and observed consolidation rates of 100% and 40%, respectively. Ribak et al.¹⁶ obtained a consolidation rate of 89% with VBG based on the 1,2 ICSRA vs. 72% with NVBG obtained from the distal radius. In turn, Straw et al.,¹³ when studying the 1,2 ICSRA-based VBG, concluded that the use of this technique was ineffective in their series, with consolidation rates of 27%, which reduced to 12.5% when considering only cases of proximal pole necrosis.

Bertelli et al.,¹⁵ using VBG based on the first metacarpal artery, observed consolidation rates in 21 of the 24 patients. Those authors prefer to use VBG due to its greater effectiveness in promoting bone consolidation when compared with NVBG, even in difficult scenarios such as avascular necrosis of the proximal pole.

The use of VBG with distal radius capsular circulation was described by Sotereanos et al.,¹⁴ that observed a consolidation rate of 80%. For these authors, this is a relatively simple technique that eliminates the need for small vessel dissection or microanastomosis, and leads to a lower risk of vascular injury.

One limitation of this technique, however, is that it fails to correct the humpback deformity of the scaphoid.

Jessu et al.¹⁷ used VBG based on the anterior transverse carpal artery, i.e., the vascularized bone graft proposed by Kuhlmann et al.³¹ They obtained a 73% consolidation rate in 30 patients with nonunion of the scaphoid; however, the two cases of proximal pole necrosis did not present consolidation. Although the authors considered their consolidation rate to be disappointing, they still considered the technique to be advantageous, mainly because of its unique volar approach that reduces morbidity, despite the fact that it requires a long learning curve.

All studies that used the 1,2 ICSRA technique highlight the easy visualization and dissection of the pedicle, which makes this technique extremely useful for the treatment of nonunion of the scaphoid with proximal pole necrosis.⁹⁻¹³ Studies on NVBG used primarily corticocancellous bone grafts, simple techniques that present the easy removal of the material as an advantage. However, a significant variation in consolidation rates was observed. Matsuki et al.¹⁹ achieved excellent results, totaling 100% consolidation in the 11 patients with necrosis of the proximal pole of the scaphoid. In turn, Robbins et al.²⁰ and Ribak et al.¹⁶ achieved much lower rates, 72% and 55%, respectively.

Final considerations

There is a preference for the use of VBG in relation to NVBG, despite the fact that the surgical technique is more detailed and demands specific training, especially in cases where vascular microsurgery is required. The studies using the VBG technique observed a better reproduction of positive results when compared with conventional bone grafts. Thus, according to this literature review, there is no consensus as to whether the use of the VBG can be effective in all cases to consolidate the scaphoid with proximal pole necrosis.

Conflicts of interest

The authors declare no conflicts of interest.

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