OBSERVATIONS
ON
THE MODE OF UNION
OF
FRACTURES OF FLAT BONES.

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THE process of reparation by which union is effected in fractured bones, has excited so much attention, and has been illustrated by the labours of so many distinguished men in this and other countries, that it seems to require some apology for again entering on such a well-cultivated field. All the experiments however which I can find recorded, that have been performed on animals for the determination of the changes going on during the union of fractures, have been made on the long or cylindrical bones; and it is only from the inspection of a few dried preparations preserved in museums, and the occasional *post mortem* examinations of patients who have died after complicated injuries, that some vague ideas respecting the processes which go on in other bones, have been derived. It has been stated that in frac-

tures of the bones of the skull, and also of the other flat, and of the spongy bones, union is effected without the formation of any external or provisional callosity; but I shall be enabled to show that this statement, though correct in some instances, is by no means generally true.

It is my intention, in the present paper, to detail several experiments which have been made on the flat bones of animals, for the purpose of ascertaining whether any essential difference exists between the mode of union of these and the cylindrical bones. The bone which I have selected is the scapula, which is easily fractured, and is essentially a flat bone; the two tables of which it is composed being in contact, in a great part of their extent: it contains however a considerable quantity of spongy tissue in the neck. The mode of union has been carefully observed in fractures traversing both these parts of the bone.

Experiment 1st.—The scapula of a young rabbit, about two months old, was fractured near the neck, 84 hours, or three days and a half, before death. On examination, the bone, with the periosteum covering it, was found to have been completely broken through, but the fragments were very little displaced. The surrounding muscles and cellular tissue were infiltrated with coagulated blood, but preserved nearly their natural texture; a small quantity of reddish-coloured gelatinous fluid was effused round the broken ends of the bones, beneath the muscles, and also partly beneath the periosteum, which was detached for a short distance from the edges of the

broken fragments. The same fluid occupied the space between the ends of the bones, and also the loose cancellous texture of the interior of the bone itself.

Experiment 2nd.—The scapula of a rabbit about three quarters grown was fractured, six days before the animal was killed. The bone was found to have been broken at some little distance from the neck, but in front of the flat portion ; it was slightly comminuted. On making a careful dissection, it was found that the muscles on both surfaces of the bone, were of their natural colour, retaining no traces of effused blood. In the situation surrounding the fracture, they were converted into a firmish gelatinous mass, in which the natural arrangement of their fibres could scarcely be distinguished. When a longitudinal section was made through this mass, and through the broken bones, the periosteum was observed torn through ; and the portions of this membrane in the neighbourhood of the fracture were thickened, and blended with the gelatinous mass formed by the deposition of lymph in the muscles and cellular texture. The periosteum was very easily separated from the surface of the bone for a considerable distance on each side of the fracture, but no new matter was deposited between them. Opposite the place of fracture, where the periosteum had been ruptured, the lymph effused externally to this membrane closely adhered to the denuded edges of the bone itself ; some firm reddish-coloured lymph was found between the fractured edges of the bone

(though not adherent to them) and in the cellular texture or diplœ of the bone.

Experiment 3rd.—The scapula of a rabbit, about the same age as the last, was fractured near the neck, and the animal was killed 12 days afterwards. On examination a considerable quantity of callus of a firm fibro-cartilaginous consistence was found encircling the ends of the bones, which slightly overlapped. The muscles were adherent to this mass of new matter, but of their natural consistence and texture. On making a section, it was found that the over-lapping portions of bone were firmly connected together by cartilaginous tissue, in which, as well as in the external callus, numerous bony particles were irregularly deposited. The callus intimately adhered to the fractured edges, which appeared to have been rounded off, and also to the external surfaces of the bone, to some distance from the place of fracture. The periosteum was so blended with the callus that it was difficult to determine whether that membrane was external to or beneath it; but it seemed to be principally in the latter situation.

These three experiments were all performed on the thick part of the scapula; I shall now relate several in which the bone was fractured through the thin flat part.

Experiment 4th.—The scapula of a guinea-pig, about three parts grown, was broken across the blade; the animal died at the end of five days. On examination it was found that the periosteum was entire, and

that there was no thickening or effusion of blood in this membrane or surrounding textures. On removal of the periosteum the portions of bone were found to be separate, but accurately in contact with each other ; and a small quantity of whitish gelatinous fluid was effused between them. There was little or no deposition of lymph along the external line of fracture beneath the periosteum.

Experiment 5th.—The scapula of a young rabbit, of about two months old, was fractured across the blade seven days before the animal was killed. On examination, no signs of fracture could be detected on the dorsum or external surface of the bone, on which the periosteum was entire. The under surface, or subscapular fossa, presented an unequal line stretching across from one side to the other. A small quantity of whitish matter of a semi-cartilaginous consistence was deposited along this line, with which the edges of the periosteum, which had evidently been here ruptured, were blended. A very considerable mass of callus was deposited over the place of fracture, on the inferior edge, or costa, of the bone. The whole scapula seemed swelled or expanded across its centre. On making a section, the external table of the bone was found to be entire, and seemed only to have been bent ; the inferior table, on the contrary, was broken through, and one fragment slightly overlapped the other. The inequality thus produced was filled up with coagulated lymph of almost cartilaginous consistence, which firmly adhered to the fractured edges, and extended over them to some

distance, beneath the lacerated portions of periosteum, which were thus separated from the surface of the bone. The *diplœ* or space between the two tables was filled with a considerable quantity of reddish gelatinous fluid, like coagulated lymph, mixed with blood, which adhered to the edges of the broken fragments, and extending between them, formed a communication with the external callus.

Experiment 6th.—The scapula of an old rabbit was fractured across the flat part, nine days before death. On examination, a considerable quantity of firm cartilaginous callus, forming a ridge, was found over the line of fracture on both sides of the bone, but in greater abundance on the inferior surface than on the dorsum. On making a section of the bone, the fractured edges were found in contact but disunited: the periosteum was closely connected with the callus, which seemed to have been deposited on both sides of that membrane, but principally on its external surface. The periosteum was firmly united to the surface of the bone up to a short distance of the margin of the fracture. Immediately over the fractured line the edges of the fragments appeared to have no connection with the callus surrounding them. The callus was partly osseous.

Experiment 7th.—The scapula of a young rabbit, about three parts grown, was fractured in the same situation as the last, ten days before the animal was killed. The appearances were the same as in the former experiment, except only that the callus was rather less in quantity. The animal had been fed

on madder, and numerous long particles of a red colour were found deposited in the callus, which was itself of the natural white colour of cartilage. The bones were generally tinged of a pink hue.

Experiment 8th.—The scapula of a young rabbit, of about two months old, was fractured thirteen days before the animal was killed. The bone was found to have been completely broken through, across its flat part, and the fractured portions overlapped at the lower edge of the scapula. When a section was made of this part, it was found that the broken edges were rounded off, and that the flat surfaces which were opposed to each other, to the extent of about a quarter of an inch, were united by ligamentous substance, which was firm and white; but in which no bony matter was yet deposited. The periosteum must have been ruptured, but a distinct membrane was stretched across the fractured part of the bone, to which the muscles were attached. At the upper margin of the scapula the fractured portion had remained in contact, the posterior fragment of the bone which was broken off having been bent downwards by the muscles, so that it overlapped the other at the lower edge, but remained in contact with it above. In the latter situation the portions of bone were united by new matter effused between the edges of the fragments, and there was no callus externally; on a section being made, a whitish cartilaginous line was found dividing the broken portions; which line was insensibly blended with the broken edges. The periosteum was

here stretched, apparently unchanged, over the fracture, and union was accomplished in the bony structure itself. The scapula was coloured with madder, but the newly-deposited matter was perfectly untinged.

Experiment 9th.—The right scapula of a full-grown guinea-pig was fractured twenty-one days before death. The edges of the bone were found overlapping each other to a considerable extent, and were united at their opposed surfaces by firm bony matter, which was strongly coloured, as well as the rest of the bone, with madder. The whole of the fractured scapula was much more deeply tinged with the dye than any of the other bones of the body. A membrane connected with the periosteum, but considerably thickened, was stretched over the projecting fragments of bone, to which membrane the muscles were adherent.

From these experiments, and many others of a similar kind, which I have performed on the scapula, it may be deduced, that union is accomplished in the thick part of this bone, exactly in a similar manner as it is in the cylindrical bones; viz., blood is first effused into the different tissues surrounding the fractured part; this blood is next absorbed, and coagulated lymph deposited in the substance of the muscles, and in the neighbouring cellular tissue, so as to form them into a solid gelatinous mass. The periosteum which has been ruptured, is separated from the fractured edges, and becomes inflamed and

thickened: lymph, which is usually of a redder colour than that which forms the external callus is also effused between the fragments themselves. At a later period, the external mass decreases in size, the muscles return to their natural texture, and a firm layer of cartilaginous matter surrounds the fractured spot, with which the periosteum is blended. This callus adheres firmly to the surfaces of the bone and dips down between the fragments, the edges of which become rounded off by the absorbents. Ossification then takes place by the deposition of earthy particles in the cartilaginous matter.

The process by which union is effected in fractures of the flat part of the scapula differs in some respects from the preceding, and also varies in different cases, in consequence of some varieties in the mode in which the fracture has taken place. In those cases in which the bone has been completely broken through, with the periosteum covering it, as in experiments 6 and 7, very little injury seems to be occasioned to the surrounding soft parts; in consequence of the bone breaking very readily, from its thinness, and the fragments suffering but little displacement, and therefore giving rise to very little inflammation or deposition of lymph in the muscles and cellular tissue, except in the immediate proximity of the broken edges. A considerable quantity of callus, however, is deposited along the line of fracture, with which the periosteum is blended, as in the fractures of other

bones, and this callus seems to become bony before any solid union is effected between the edges of the bone itself.

In most of the cases which I examined, I found a considerable difficulty in determining whether the periosteum was on the external surface, or between the callus and the bone, it being closely blended with the cartilaginous mass. Mr. B. Cooper seems to agree with this statement; for he says that in that stage when the effused matter has attained "the appearance, firmness, and elasticity of cartilage," . . . "this membrane is inseparably connected with the surrounding mass, much thickened, and easily detached from the bone, so as to give the appearance of the bone having been deprived of its periosteal covering; but the fact is, that it has only become *blended* with the effused callus." * Miescher, who is one of the most recent writers on this subject, makes two distinct stages in the formation of the provisional callus. In the first stage, the periosteum, cellular tissue, and muscles, he says, "all become swelled, indurated, and conneed together, encircling the fracture as with a capsule." In the other stage, lymph is effused within this capsule, which forms the true callus, becoming bony, and is exuded from the surface of the bone itself. All this is perfectly correct, and I have seen this lymph, which is first effused in a reddish semi-fluid state, separating the bone from the periosteum. Miescher states, however,

* Guy's Hospital Reports, vol. ii. p. 195.

that when the latter substance has assumed a firm and vascular state, the external capsule is entirely absorbed and disappears ; so that the periosteum lastly forms the external covering of the callus. My observations do not verify this description in *all* cases, though in many it is undoubtedly true ; for in several instances where the callus had become partly osseous, the periosteum could distinctly be traced into the interior of the mass, and appeared to be much nearer to the internal than the external part of it. The true explanation seems to be, that though the greater part of the matter effused among the muscles and into the surrounding textures becomes quickly absorbed, yet it is not necessarily all removed, and that portion may remain which is in contact with the external surface of the periosteum ; and, together with that membrane, may become blended with the callus effused from the surface of the bone itself. If I were to hazard a conjecture in what cases this will be likely to occur, I should say, in those where the periosteum has been separated for a little distance only, from the surface of the bone ; for, as Mr. Gulliver has remarked, “ the formation of new bone generally commences at the point where the periosteum separates from the shaft of the bone, so that the size of the external case of osseous matter seems to be determined by the extent to which the periosteum has been detached from the bone by the violence of the injury.”*

* Edin. Med. and Surg. Journal, vol. xlv. p. 54.

Now, in a thin bone like the scapula, the degree of injury produced by the fracture is so slight, that in many cases the periosteum may not be detached for a sufficient distance to allow space for the formation of a mass of provisional callus which will effect the purposes intended to be answered by it ; which, according to Dupuytren, are to prevent motion between the fragments ; and in these cases it is probable that part of the external capsule remains. In the sixth experiment which I have related, the periosteum was found firmly attached to the surfaces of the bone up to the very margin of the fracture, and there was a considerable quantity of firm, and partly osseous callus, external to this membrane.

I have stated that the process of union of fractures of the flat part of the scapula varies in certain cases. I will now endeavour to point out these particular instances. In many experiments which I have performed, I have found that union is accomplished without the formation of any provisional callus. In the greater number of these cases the periosteum had remained entire, as in the fourth experiment which I have related ; and I am inclined to suppose, that this circumstance will partly account for the absence of callus. In the first place, the fractured edges being prevented by the entire state of the membrane from irritating the muscles and surrounding textures, the inflammation which gives rise to the effusion of lymph and consolidation of these textures, so as to form the external capsule, is not produced : and the preliminary steps

in the formation of the provisional callus are wanting. In the second place, however, why is it that little or no exudation takes place from the surface of the bone beneath the periosteum, so as to form a ridge under this membrane? The only explanation which I can find for this is, that the periosteum is very little separated from the surface of the bone in these cases, and lymph seems only to be effused where the connection between these parts is destroyed. I find it mentioned by writers, that cylindrical bones are sometimes broken without the periosteum giving way. Mr. Gulliver refers to a specimen preserved in the Museum of the King's College, London, where both bones of the fore-arm of a child were fractured, without the periosteum being injured. He does not say, however, whether any callus was here formed. I can scarcely conceive it possible that the cylindrical bone of an adult can be broken without the periosteum giving way at the same time; at any rate, on one side. In a few cases, which I have noticed, where no provisional callus had been formed, the periosteum had apparently given way, and here the only reason that can be assigned for the absence of callus is, that the broken fragments had remained accurately in contact, and the direction of the fracture had been such, that complete immobility had been preserved; under which circumstances it has been premised, that union might take place, simply by the deposition of ossific matter between the extremities of the fragments. It has been said, that where union is ac-

complished without the formation of provisional callus, the process is very slow ; but in the eighth experiment which I have related, the upper edges of the fracture which had remained in contact, and which were covered by periosteum, were united by new matter effused between the fractured margins, as early as the thirteenth day ; which new matter was of a cartilaginous consistence, and insensibly blended with the broken edges, and would doubtless soon have become osseous.

In the course of performance of the preceding experiment, I noticed one or two other facts, which I shall briefly state in concluding the present paper.

It has been stated by Macdonald, and repeated by other authors, that the cartilaginous matter forming callus, differs from true cartilage by becoming tinged red, when the animal has been fed on madder. I have distinctly observed that this is incorrect in many cases ; the bones of the body generally having been found coloured, as well as the new bony particles deposited in the callus ; while the cartilaginous matter surrounding these fragments has been perfectly white. I have been, by this means, enabled to observe, that the new bony particles are deposited irregularly through the provisional callus, and do not first arise from the surface of the old bone.

The lymph effused from the edges of the fractured bones themselves, and which fills up the interval between them, differs from that forming the provisional callus, in having a peculiar red gra-

nulated appearance. Mr. Howship, and latterly Mr. B. Cooper, consider that the coagulated blood plugging up the ends of the bones, actually becomes organised ; but I could not find any other point of resemblance between this new effused matter and coagulated blood, besides the reddish colour.

I shall here conclude the present communication, and may observe, that the process of union in fractures of the scapula differs in very few, if any, respects, from that of the common cylindrical bones.