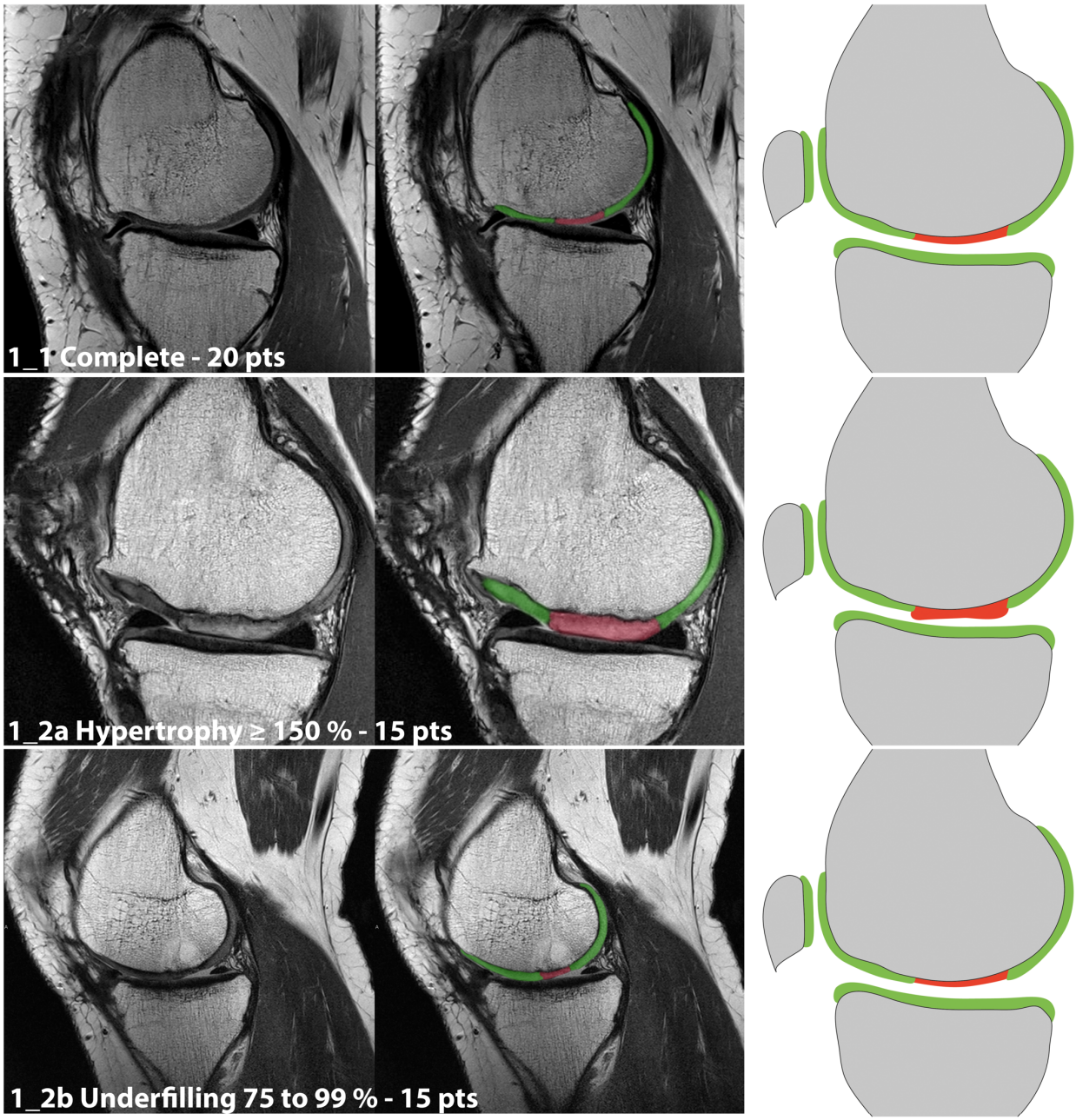
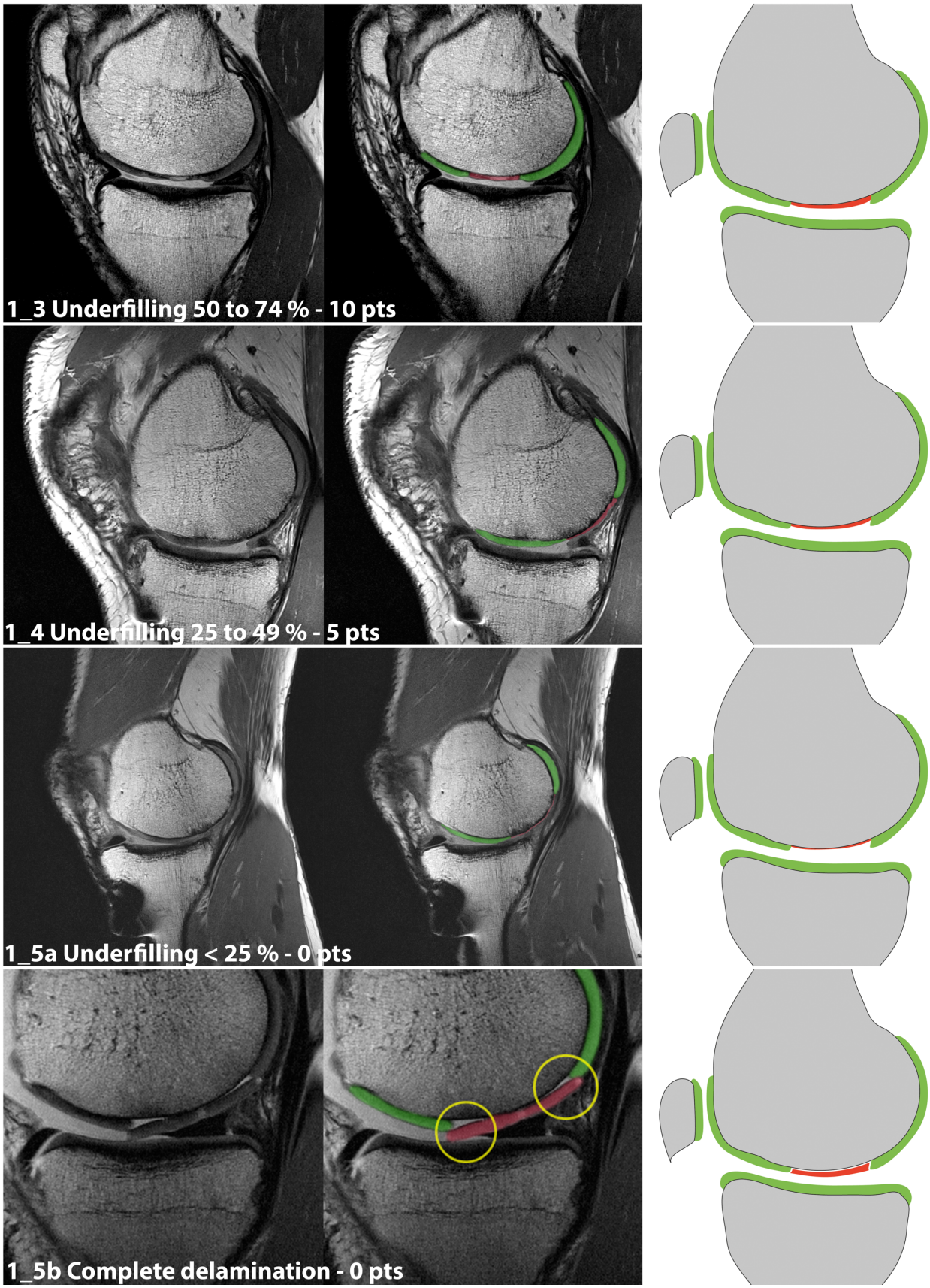
Magnetic Resonance Observation of Cartilage Repair Tissue (MOCART) Knee Score 2.0 – Complementary Atlas

1.) Volume of cartilage defect filling



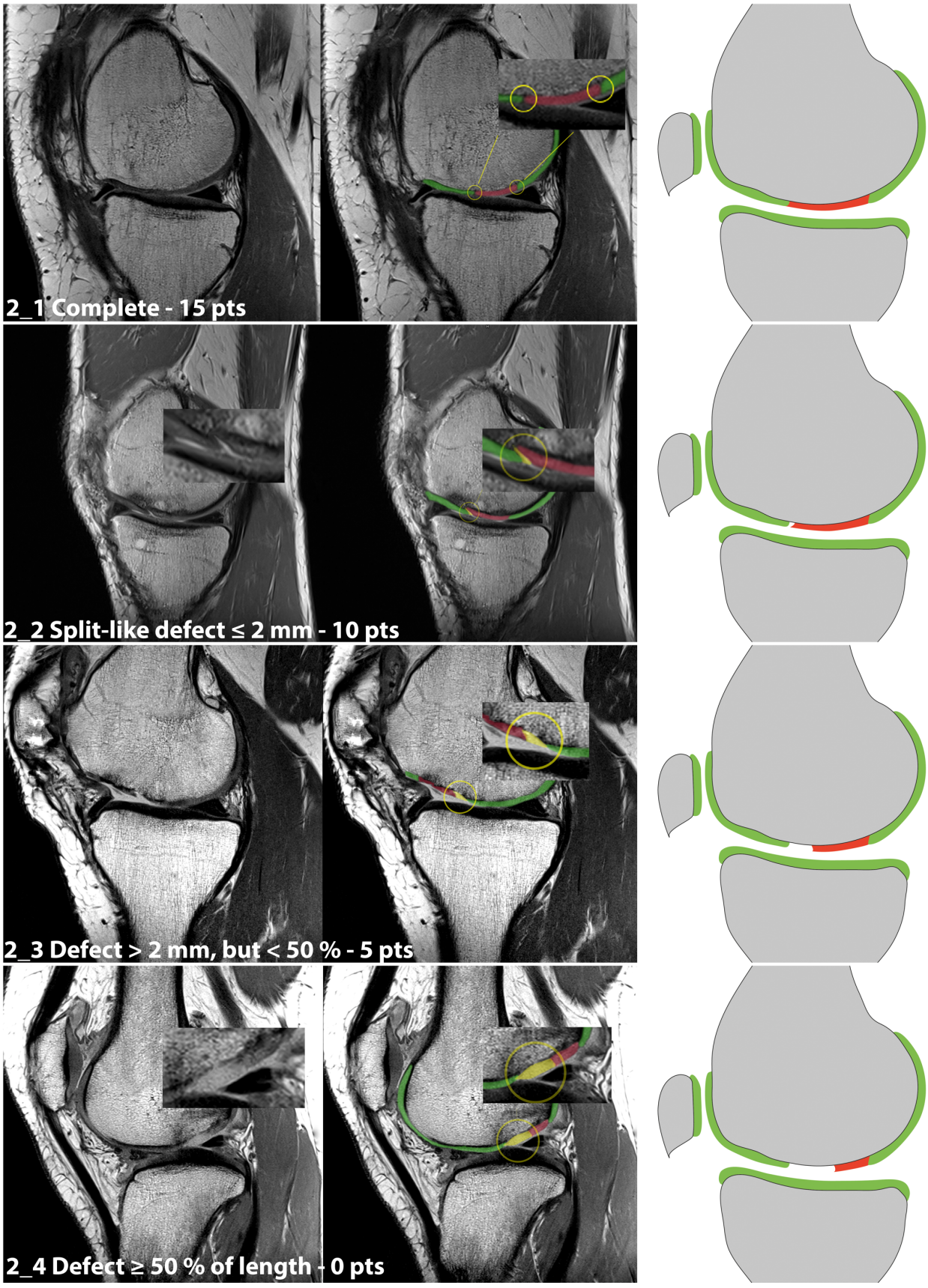

1_3 Underfilling 50 to 74 % - 10 pts
1_4 Underfilling 25 to 49 % - 5 pts
1_5a Underfilling < 25 % - 0 pts
1_5b Complete delamination - 0 pts

The volume of cartilage defect filling must be assessed in relation to the adjacent native reference cartilage and must be described as a percentage of the hypothetical volume of intact cartilage that covers the defect.

An evaluation in at least two different planes is necessary to prevent misinterpretations and to avoid underappreciating graft hypertrophy, especially in sequences with fat suppression in which the repair tissue can be of almost fluid-like signal when using suboptimal windowing.

The filling is considered to be complete (100%) when the repair site is as thick as the surrounding reference cartilage, with a repair tissue volume equivalent to the hypothetical volume of healthy cartilage that covers the defect. (1_1). An incomplete repair with inferior cartilage filling compared to adjacent native regions is classified as underfilled and can be classified as “minimal” (75 – 99%, 1_2b), “minor” (50 – 74%, 1_3), “moderate” (25 - 49%, 1_4), or “severe” (< 25%, 1_5a). Minor hypertrophic filling <150% is scored the same as complete filling. Hypertrophy of ≥ 150% (1_2a) will be rated with the same score as minimal (75 – 99%) underfilling. Complete delamination in situ (**Fehler! V erweisquelle konnte nicht gefunden werden.**_5b) receives the same score as severe underfilling as it bears the risk of dislocation and exposed subchondral bone. Morphologically, delamination is characterized by a complete fluid-like interface that surrounds the repair tissue, which renders healing unlikely.

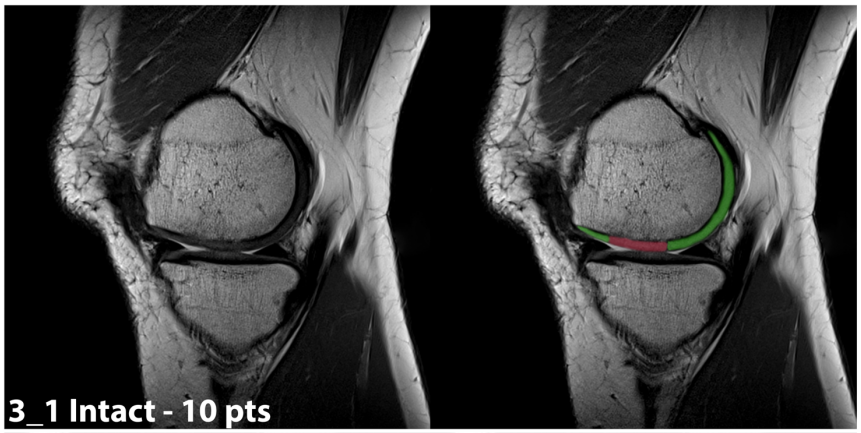
2.) Integration to adjacent cartilage and underlying bone



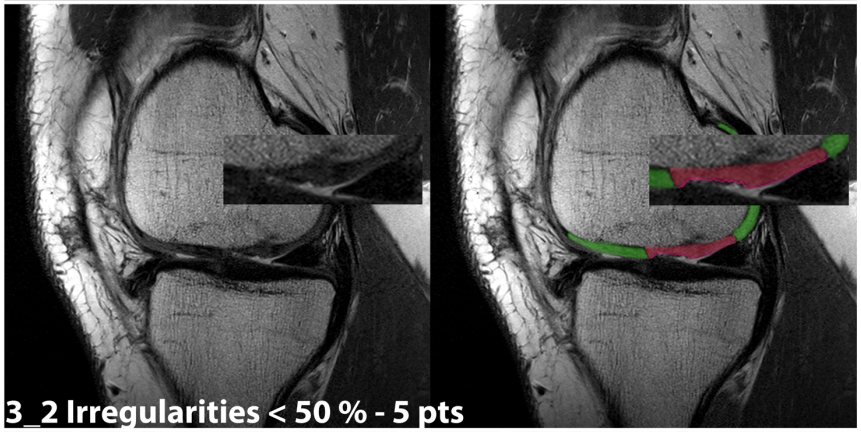
This variable serves as a measure of the integration of the cartilage repair tissue into the neighboring native cartilage by evaluating the interface between these two tissues. The variable disregards integrational defects of the underlying cartilage-bone interface to better distinguish between integration and the variable 6 – “bony overgrowth of bony defect” and 7 – “subchondral changes”.

Integration is classified as complete (2_1) in cases of an indiscernible interface between the repair tissue and the adjacent cartilage. In case of a split-like demarcation line between the repair tissue and the adjacent cartilage, the width of this defect must be determined. The variable discriminates between split-like defects ≤ 2mm (2_2), defects > 2mm but < 50% of the repair tissue length (2_3) and defects ≥ 50% of the repair tissue length (2_4).

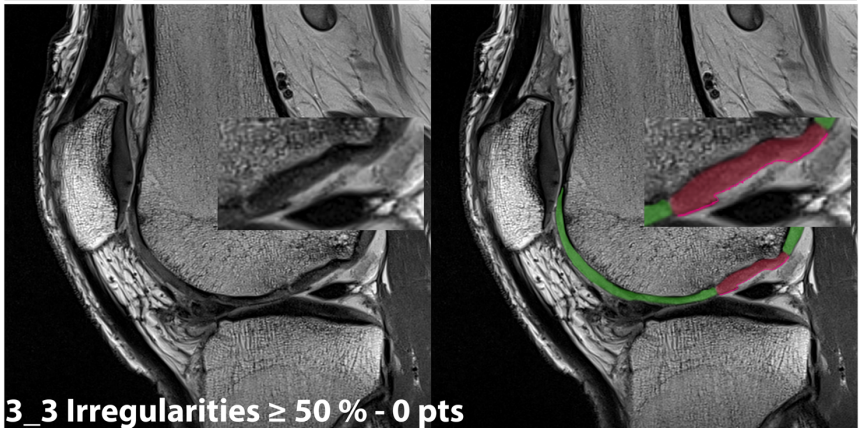
3.) Surface of the repair tissue



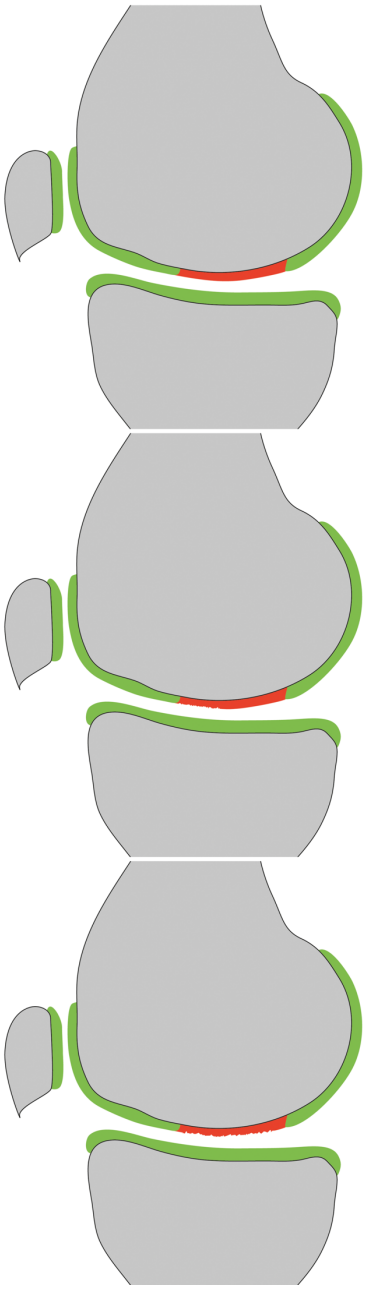
3_1 Intact - 10 pts



3_2 Irregularities < 50 % - 5 pts



3_3 Irregularities ≥ 50 % - 0 pts

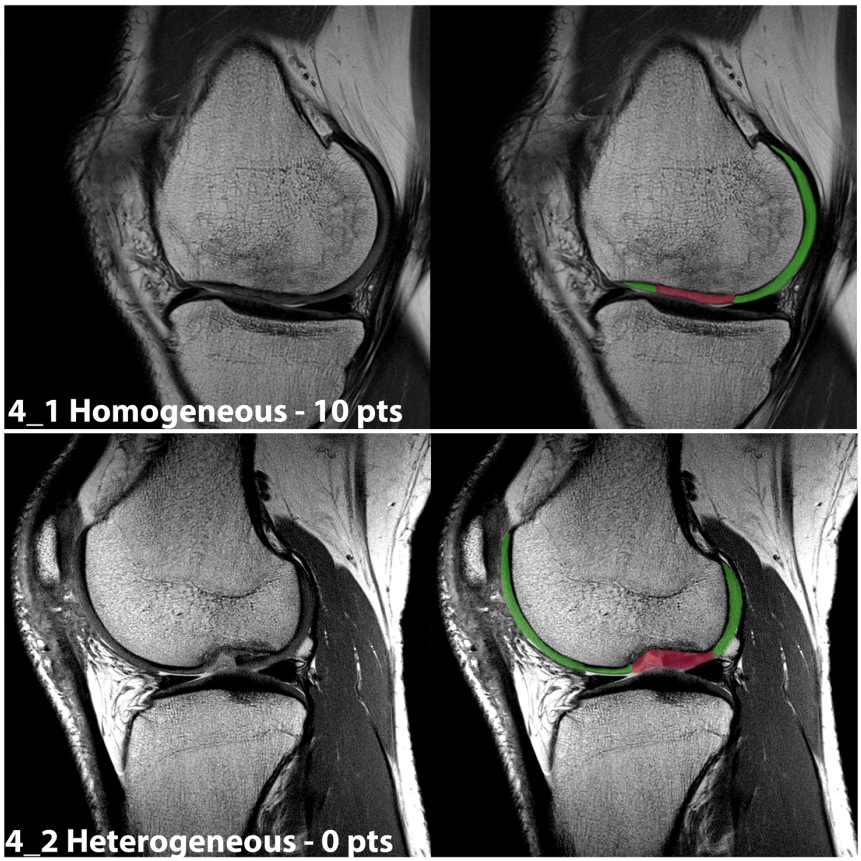


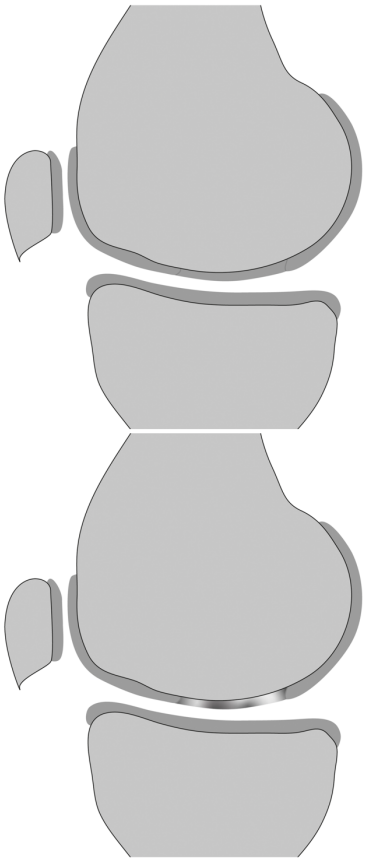
The surface of the repair tissue is classified as “intact” in case of a preserved, congruent articular surface (3_1). Irregularities of the articular surface may range from minor fibrillations to fissures and ulcerations. These irregularities are further differentiated based on their extension over the total repair tissue diameter and are subdivided into two grades with either an extension over less (3_2) or more (3_3) than 50% of the repair tissue diameter.

It is important to assess the surface of the repair tissue independently of the volume of cartilage defect filling. The surface has to be evaluated with respect to present irregularities, regardless of complete filling, present hypertrophy or underfilling.

To be able to visualize fine fibrillations and fissures on the surface of the repair tissue, high-resolution MR imaging protocols are essential.

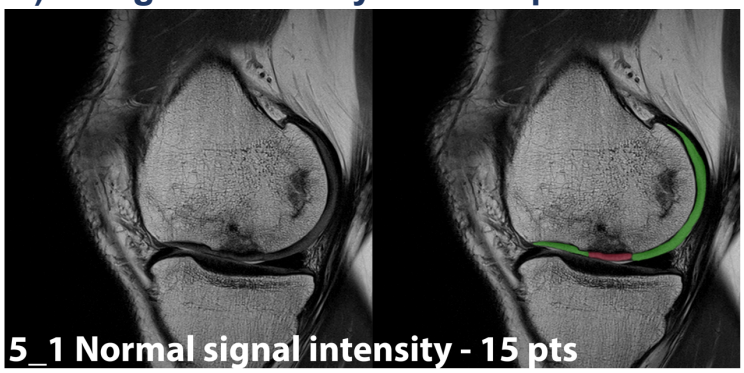
4.) Structure of the repair tissue

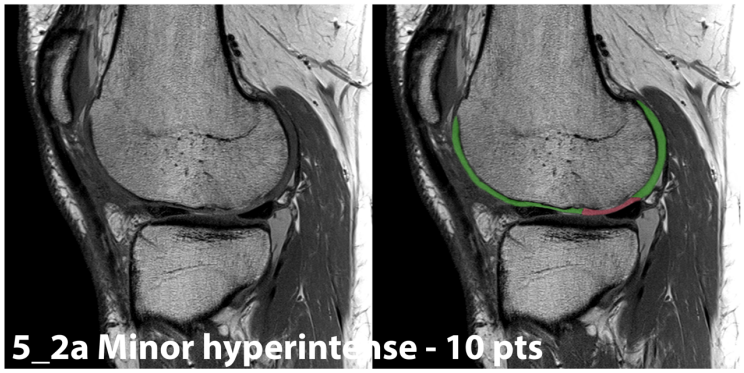


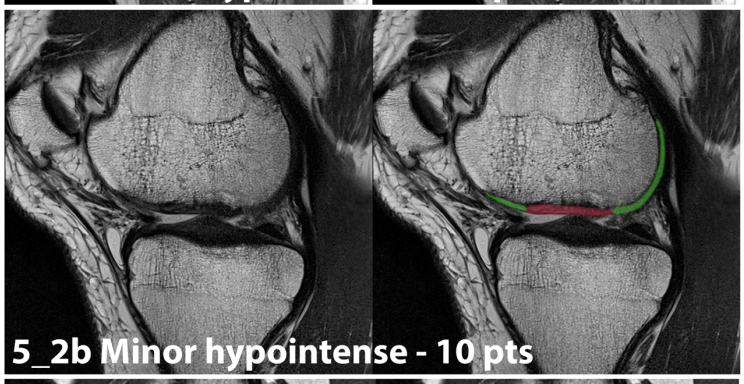


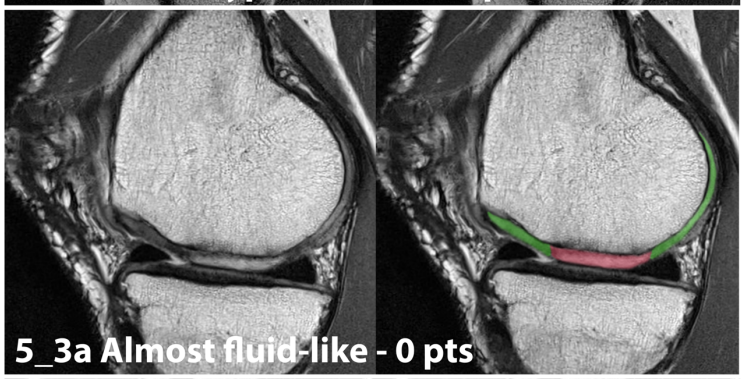
The structure of the repair tissue is defined as homogeneous when typical cartilage layers are formed over the entire repair tissue or the repair tissue appears homogeneous (4_1). It is classified as inhomogeneous (4_2) when the tissue appears disorganized with alterations in signal intensity indicating a heterogeneous repair tissue structure.

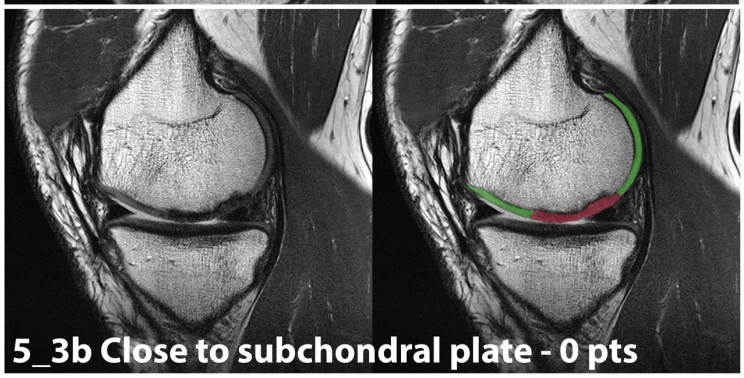
5.) Signal intensity of the repair tissue

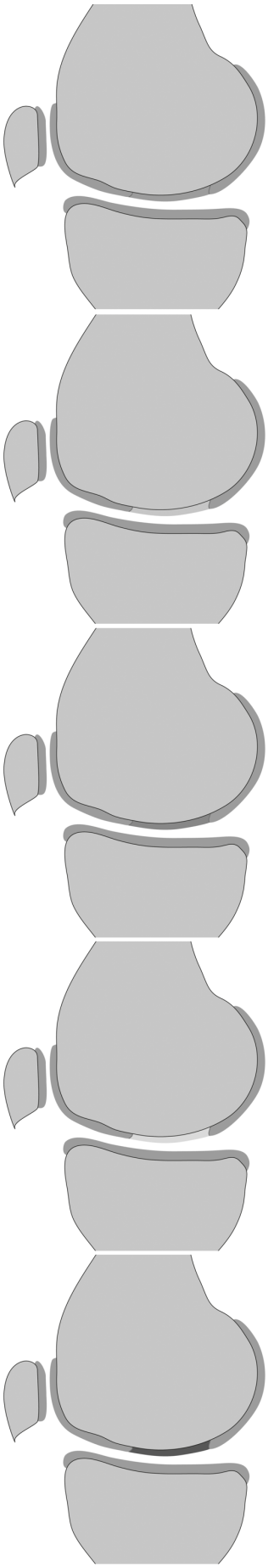










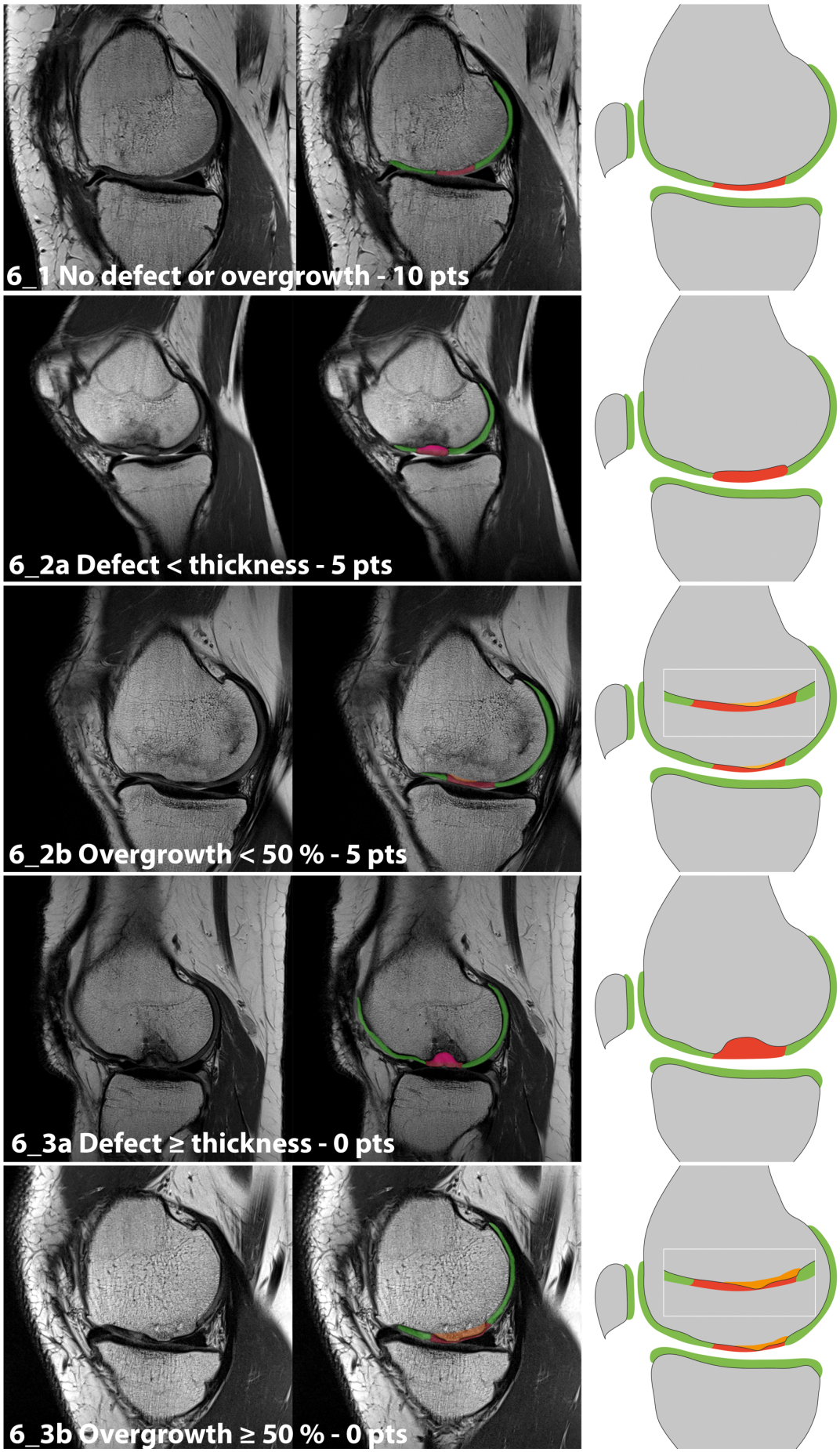


The variable “signal intensity of the repair tissue” is recommended to be assessed on fat-saturated PD TSE sequences, which offer high sensitivity for the intrachondral structure of cartilage. The signal intensity of repair tissue can be rated as “normal” (isointense to adjacent native cartilage – 5_1), “minor abnormal,” (5_2a – minor hyperintense and 5_2b – minor hypointense) and “severely abnormal” (5_3a – almost fluid like signal 5_3b – close to subchondral plate signal). In contrast to the original MOCART score, signal alterations of the repair tissue can be rated hyper- or hypointense on the fat-saturated PD TSE sequence. The signal intensity should be evaluated on all fat-saturated as well as non-fat-saturated PD-TSE sequences.

A pathological finding on one sequence is sufficient for grading as “abnormal”, however the pathology should be present in more than one slice to avoid wrongful interpretation of a partial volume effect or artifact. In addition, the worst present feature defines the scoring e.g. if the repair tissue shows minor hypointensity and major hyperintensity in different regions, it should receive 0 points.

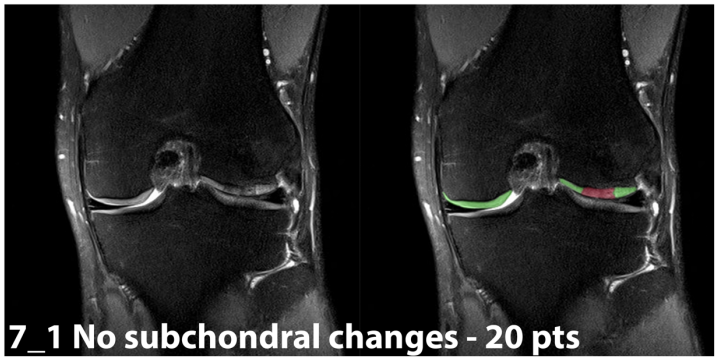
Furthermore, the magic angle effect has to be considered when evaluating the signal intensity of the repair tissue. Should the repair tissue be located at the anterior or posterior condyles at an angle close to 55° to the B0, the intensity should be evaluated in reference to healthy reference cartilage, which is positioned at the same angle to the magnetic field, to avoid false positive scorings. While a hyperintensity of the repair tissue may represent a higher water content and disorganization of the collagen fiber network, a hypointensity of the repair tissue on the same sequence may result from fibrous tissue formation.

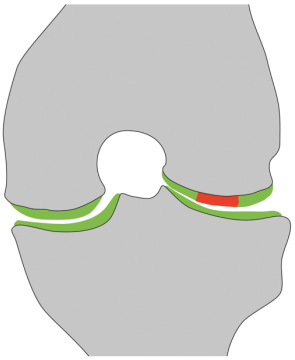
6.) Bony defect or bony overgrowth

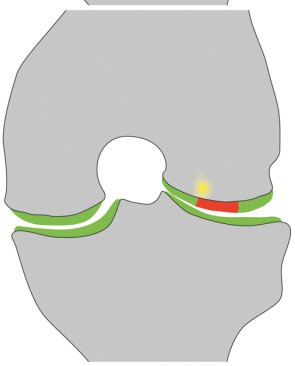


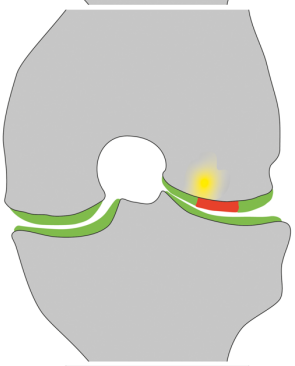
Cartilage repair with intact subchondral bone and no presence of intrachondral osteophytes should be rated as “no bony defect or bony overgrowth” (6_1). Bony defects should be subcategorized in defects shallower than the thickness of the adjacent native cartilage (6_2a) and as deep or deeper (6_3a) as the thickness of the adjacent native cartilage. Bony overgrowth should be subcategorized in bony overgrowth < 50% (6_2b) and ≥ 50% (6_3b) of the thickness of adjacent native cartilage. The depth of the bony defect or bony overgrowth should always be assessed using the adjacent native cartilage as reference, especially in case of an underfilling of the defect, in which the repair tissue thickness as reference might produce a false positive result.

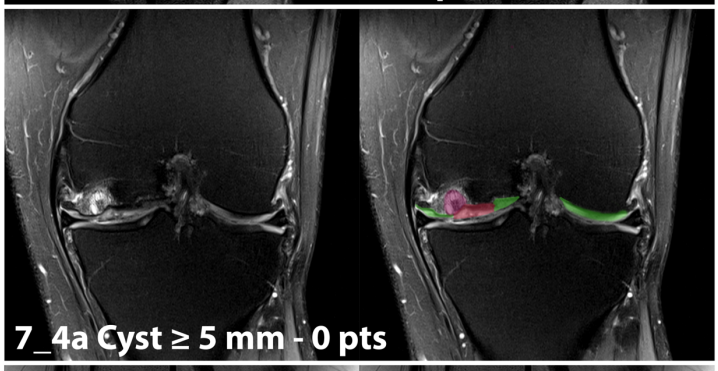
7.) Subchondral changes

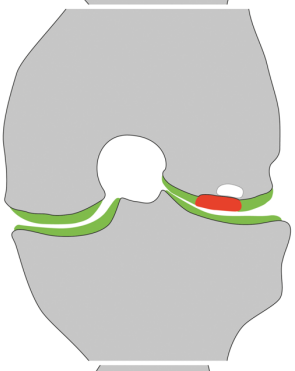


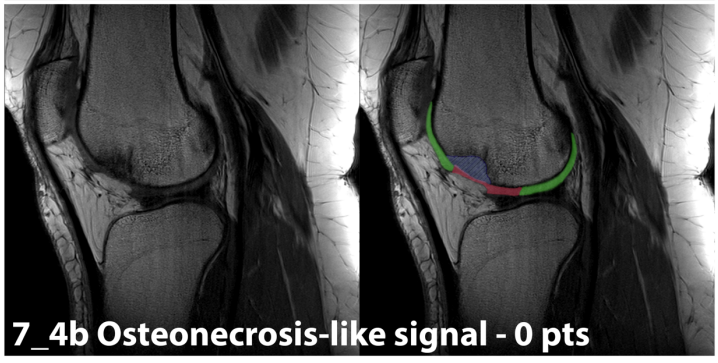


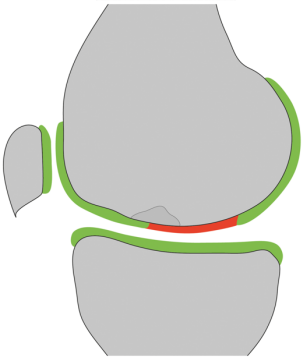












In case of an intact subchondral lamina and no additional pathologies, the variable “subchondral changes” is rated “intact” (7_1). Edema-like marrow-signal can be subdivided into minor, with a maximum diameter less than 50% of the repair tissue diameter (7_2), and severe, which exceeds 50% or the repair tissue diameter (7_3).

For subchondral cysts with an individual or combined diameter ≥ 5mm (7_4a) or osteonecrosis-like signal (7_4b), zero points are allocated in this variable. If more than one subcategory of this variable is present in one patient, the subcategory with the less favorable scoring defines the points allocated, i.e. if minor edema-like-marrow-signal and a subchondral cyst are observed, 0 points are selected for this variable.