

sintered to remove the fine pores between the particles in the walls of the macropores, which results in an improvement in the mechanical strength. Directional freezing of the suspensions leads to growth of the ice in a preferred direction, resulting in the formation of porous scaffolds with an oriented microstructure. The technique has been used to produce porous polymer, glass, and ceramic scaffolds (Schoof et al., 2001; Zhang et al., 2005; Deville et al., 2006b; Song et al., 2006; Fu et al., 2008a,b, 2010a,c; Liu et al., 2011; Wegst et al., 2010). A benefit of the oriented microstructure is higher scaffold strength in the direction of orientation, compared to the strength of a scaffold with a randomly oriented microstructure (Deville et al., 2006a). HA scaffolds have shown unusually high compressive strength in the orientation direction, up to four times the value for similar materials with similar porosity but randomly arranged pores. These strengths allow their consideration for load-bearing applications. Both 45S5 and 13–93 glass scaffolds have been prepared using the technique (Song et al., 2006; Fu et al., 2010a). However, oriented scaffolds prepared from aqueous suspensions typically have a lamellar microstructure, with a pore width in the range 10–40 μm that is considered to be too small to support tissue ingrowth.

It has been shown that the addition of an organic solvent such as (1,4-dioxane to the aqueous solvent) (Fu et al., 2010a), or the use of an organic solvent such as camphene (Liu et al., 2005), results in a change in the lamellar microstructure to a columnar microstructure and an increase in the pore width. Bioactive glass (13–93) scaffolds with columnar microstructures and pore diameters of 100–150 μm have been prepared (Fig. 15.1E and F). In addition to their higher strength, these oriented bioactive glass scaffolds have shown the ability to support cell proliferation and differentiation *in vitro*, as well as tissue infiltration *in vivo* (Fu et al., 2010a,c).

15.4 MECHANICAL PERSPECTIVE

A typical long bone of the limbs is composed of two types of bone, each having a different structural organization: cortical bone, also referred to as compact bone; and trabecular bone, also referred to as cancellous or spongy bone (Fratzl et al., 2004). Comprised mostly of an inorganic phase (HA) and an organic phase (collagen), cortical bone has a unique combination of strength and toughness. Cortical bone has a compressive strength of 100–150 MPa in the long direction, and a flexural strength of 135–193 MPa (Table 15.2). The fracture toughness, K_{Ic} , of cortical bone (2–12 $\text{MPa m}^{1/2}$) has an upper range that is much higher than the values for most ceramics and inorganic glass (typically $K_{Ic}=0.5\text{--}5 \text{MPa m}^{1/2}$ for ceramics and $0.5\text{--}1 \text{MPa m}^{1/2}$ for glass). As shown in Fig. 15.2, extrinsic toughening mechanisms, such as microcracking, crack bridging, and deflection, are the primary factors contributing to the high fracture toughness of human cortical bone (Launey et al., 2010).

As described in the previous section, scaffolds with a wide range of microstructures can be obtained depending on the materials and fabrication techniques