Contribution of hydroxyapatite to the tensile strength of the isobutyl-2-cyanoacrylate-bone bond

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The bonding strength between bone and α-2-cyanoacrylate polymers, with or without the addition of powdered hydroxyapatite, was determined. The tensile strength of a bone-cyanoacrylate bond was measured for each polymer: 4.31 ± 0.88 MPa (methyl-), 5.74 ± 0.62 MPa (ethyl-), and 8.33 ± 0.41 MPa (isobutyl-). The tensile strength of the isobutyl-2-cyanoacrylate bond increased to 12.03 ± 0.72 MPa with the addition of 10% (w/v) hydroxyapatite before decreasing to 7.89 ± 0.59 MPa on addition of 15% (w/v) hydroxyapatite. An optimal concentration of hydroxyapatite significantly increased the tensile strength of a bone-cyanoacrylate bond in vitro in a manner comparable to reinforced bone replacement materials.

Keywords: Hydroxyapatite, bone, cyanoacrylate, adhesives

The α-2-cyanoacrylates have been used in experimental bone fracture repair for many years. Recent applications include repair of osteochondral fractures of the femoral condyle in the dog and transverse fractures of the tibia and femur in the rat and rabbit, respectively. Recent studies have also reported on the bonding strength and bond durability of cyanoacrylates with bone, and on the contribution of bone remodelling to the strength of the adhesive bond.

In part, the difficulty associated with the application of this class of adhesive to bone fracture repair is due to the elastic behaviour of cortical bone. The complex biomechanical properties of cortical bone are especially evident in the development of bone composite analogues. Some success has been obtained in the development of bone replacement materials by increasing the stiffness of carbon fibre and glass fibre-reinforced polymers with the addition of particulate hydroxyapatite. In addition, calcium phosphate ceramics have been employed as bone tissue replacements in a variety of cases.

The purpose of the present study was to determine whether addition of hydroxyapatite would enhance the bonding strength of cyanoacrylate adhesives to bone when quantitated by measurement of tensile strength.

MATERIALS AND METHODS

Specimens

The source of bone was the distal tibial segment of the adult rat forequarter. After dissection, the fresh bone specimens were cleaned and milled to 8 mm diameter cylinders. Further machining and processing of the bone was performed according to a previously published method.

Adhesives

Methyl-, ethyl-, and isobutyl-2-cyanoacrylate were purchased from Vigor Co., New York, NY. Hydroxyapatite (Ca₁₀(PO₄)₆(OH₂)) was purchased from Fisher Scientific Co. (Fairlawn, N.J) as an ACS certified reagent. An electric mill was used to grind the hydroxyapatite crystals to approximately 50 μm diameter, as confirmed by electron microscopy. The adhesives were uniformly applied as a thin film to the bone ends to be joined, and cured for 5 min at r.t. The surfaces of the bone ends were not primed or altered following machining. The glued bones were kept in an ice-cold balanced salt solution until testing (up to 2 h). Addition of 10% (w/v) hydroxyapatite to isobutyl-2-cyanoacrylate did not significantly alter spreadability. The sessile-drop method (Lorentzen–Wettres goniometer) was used to measure the contact angle: 55 ± 2° (isobutyl-2-cyanoacrylate) and 51 ± 2° (composite), for triplicate determinations.

Measurement and testing

The test for tensile strength of adhesives to bone, as previously introduced by researchers at the National Bureau of Standards, was performed on the bone specimens. Five bone samples were tested in each experimental condition and the results were reported as the mean and standard deviation for the five determinations.
The results from this study agreed closely with previous studies. The mechanical properties of porous ceramics decreased with increasing amounts of micro- and macro pores. Perhaps, in the present case, the relative amount of micropores or macropores reached a threshold at approximately 10% (w/v) hydroxyapatite, and addition of more hydroxyapatite resulted in increased micropore formation that ultimately resulted in decreased adhesive-bone tensile strength (i.e., at 15% (w/v) hydroxyapatite).

The results suggested that hydroxyapatite-reinforced bone bonding with cyanoacrylate adhesives may be useful in applications where high tensile forces are encountered in the repair of skeletal structures. For example, one application of a hydroxyapatite-cyanoacrylate composite may be in the area of fracture repair in long weight-bearing bones (e.g., femur), or in the repair of fractures in the bones of the foot and hand. Furthermore, other natural or synthetic materials, more suitable for other tissues, may be useful in enhancing the bonding strength of the alkyl-2-cyanoacrylates in a range of biological applications. Further investigation is directed to this end.

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REFERENCES