Sea-urchin inspired wet bioadhesives - a multidisciplinary quest towards biomimicry

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INTRODUCTION: Adhesive mechanisms are beginning to be deciphered in some marine organisms that attach permanently with a cement (mussels, barnacles) or use a viscous film to move and adhere (limpets). However, this is far from being true for sea urchins, that attach strongly but temporarily to the substratum. Sea urchins are exclusively benthic animals and to withstand hydrodynamic forces rely on hundreds of independent adhesive organs, their adoral tube feet, specialized in locomotion and anchoring. Tube feet consist of two functional units: a disc, which makes contact with the substratum, and a stem, which connects the disc to the test. Therefore, the tenacity with which an individual can anchor to a surface is determined by the strength of its numerous tube feet which, in turn, depends on the tensile strength of the stem and the adhesive power of the disc. The later is determined by the chemical properties of an adhesive secretion that is able to functionally assemble underwater and displace water, ions, and weakly bound polyions, properties that are rarely achieved by synthetic adhesives. In addition, sea urchins also possess an effective de-adhesive secretion that rapidly releases the tube feet in order to begin a new attachment-detachment cycle. This de-adhesive secretion is believed to contain enzymes, which catalytic activity promotes breaking of the bonds established between the adhesive and the disc, thus leaving a circle of adhesive material (footprint) strongly attached to the substrate.

METHODS & RESULTS: More than 10 years of research combining morphological and biomechanical techniques have provided evidence that tube feet discs attach with a tenacity (adhesive force per unit area) similar to other marine and commercial adhesives, being able to cope with different substrate chemistries and roughness, thus ensuring strong adhesion irrespective of substratum profile or chemistry. These findings demonstrated that sea urchins tube feet have evolved to resist hydrodynamic loads and deal with the unpredictability of the substratum, which has not yet been achieved by any synthetic (chemical-based) adhesive when applied in an underwater environment. More recently, techniques such as proteomics and mass spectrometry, demonstrated that tube feet are unique mechano-sensory adhesive organs and highlighted putative adhesive proteins. Work is in progress to identify the genes coding for these adhesive proteins in order to produce recombinant analogues or partial adhesive motifs that can be used to design new dental bioadhesives inspired on millions of years of optimization through biological selection.

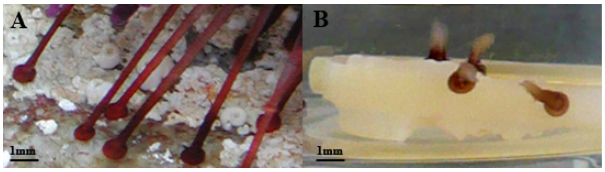

Fig. 1: Images of sea urchin tube feet attaching underwater to the surface of a rock (A) and to enamel and dentine in a human tooth slice both in (B).

DISCUSSION & CONCLUSIONS: Adhesives produced by marine attaching organisms have attracted attention as a paradigm of strong and versatile underwater adhesion. Given the similarity between the oral environment and the wave swept seashore it is highly probable that water-efficient marine adhesives can be valuable sources of inspiration to develop new dental adhesives. Although a number of improved dental adhesives have become available commercially there are still a number of unsolved problems, reinforcing the need to develop new biomimetic adhesives based on the knowledge of the molecular mechanisms underlying marine adhesion.

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