BONE MATERIAL STRENGTH INDEX TO DIFFERENTIATE EARLY BONE STRUCTURE IN PATIENTS AFFECTED BY CRANIOSYNOSTOSIS

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Introduction

Craniosynostosis (CS) is a congenital craniofacial malformation, which involves premature cranial suture closure, leading to restricted brain growth and aesthetic problems [1]. Although surgical intervention reduce risk of raised intracranial pressure and normalise the head shape, unpredictable outcomes and incomplete correction of deformities have been reported. Furthermore, diagnosis of CS relies on physical and radiographic examination. Determining the material properties of the cranial bone in CS patients would provide an insight into bone response to surgical procedures [2]. However, the assessment of skull bone quality (SBQ) based only on the radiographs remains elusive and high radiation doses limit the number of patients receiving this examination. OsteoProbe (Active Life Scientific) is a portable handheld micro-indenter, specifically designed for clinical practice. Osteoprobe quantifies bone's resistance to indentation as bone material strength index (BMSi). The aim of this study was to investigate if BMSi can be used as a biomarker to predict final head changes in craniofacial procedures.

Method

Following ethical approval, cranial bone samples were collected from 34 patients (age: 17 ± 34 months) surgically treated for CS correctioin at GOSH (London, UK).

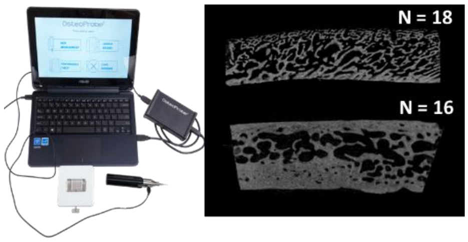

Figure 1: Osteoprobe microindenter (left); one- (top) and three-layered (bottom) bone samples

Upon retrieval, samples were kept frozen at –20°C until examination. Specimens' structures were characterized using micro-CT (μCT, Skyscan 1172), using a voxel size of 8.94 μm, a source voltage of 49 kV a source current of 200 μA and a 0.5mm aluminum filter. Bone thickness, bone volume fraction BV/TV, BMD and specific bone surface BS/BV were quantified using CTAn. Bone material quality was examined using Osteoprobe and BMSi was recorded for each bone sample. Surgical outcome was assessed by changes in cephalic index (CI, defined as cranial width over length) pre and post operation.

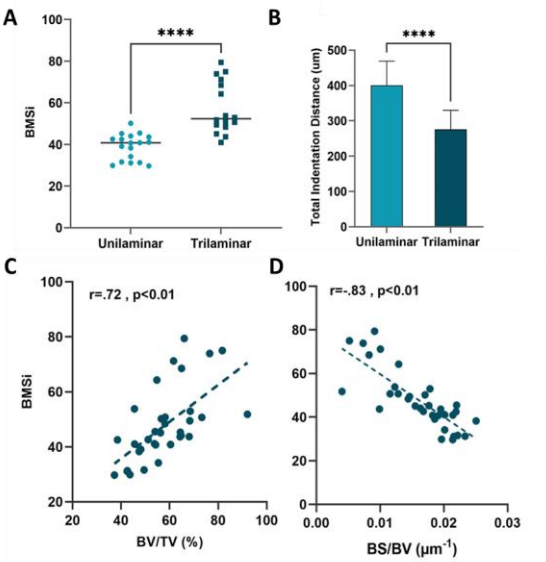

Figure 2: Difference in BMSi (A) and indentation depth (B) between one- and three-layered; correlation between BMSi and BV/TV (C) and BS/BV (D).

Results

Based on μCT appearance, bone structure was classified into one- (n-18) or three-layered (n = 16). Our results revealed change in CI was significantly higher in one-layered sample (3.4 ± 2.8%) compared to three-layered (0.5 ± 4.2 %, p=.04). Using OsteoProbe differences in the structure of the bone samples were identified: a significantly higher BMSi was determined when three-layered and one-layered samples (57.5 ± 12.5 vs 38.9 ± 6.2, p<0.01) were compared. Significant higher BV/TV (p<0.01), bone thickness (p<0.01) and BMD (p<0.05) were found in trilaminar structure. BMSi was positively correlated with BV/TV (r = 0.72, p<0.01) and BMD (r = 0.35, p = 0.04) and negatively correlated with BS/BV (r = -0.83, p<0.01). In addition, lower BMSi values were associated with larger increase in CI (r=-0.4, p=.04). No correlations were found between patients age and CI.

Discussion

Microstructural and material differences between one- and three-layered bone structures were shown: Osteoprobe is a promising technique enabling physicians to evaluate in vivo tissue-level material properties of bone in a minimally invasive, simple and safe manner.

References

1. Fearon, PRS, 133(5): 1261, 1275, 2014.
2. S. Ajami et al., JMBBM, 125:104929, 2022.