Title Page

Title: INVESTIGATING THE CORRELATION BETWEEN BONE DENSITY AND FRACTURE FREQUENCY IN THE MANDIBULAR CONDYLE WITH MICRO-COMPUTED TOMOGRAPHY

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Investigating the correlation between bone density and fracture frequency in the mandibular condyle with micro-computed tomography

Abstract

Fractures of the mandibular condyle are common and include diacapitular fractures affecting the condylar head. The medial part of the condylar head is least commonly fractured, possibly due to decreased propensity for lines of force to run in the region. Micro-computed tomography (X-ray microtomography) of five temporomandibular joint specimens was conducted to explore whether trabecular bone structure correlates positively with fracture prevalence; which could reflect adaptation in response to lower exposure to physiological loads throughout life. Models of trabecular bone, and graphic representation of bone density indicated least dense bone medially, but a statistically significant ANOVA result was not obtained. Further study is required to verify whether a relationship between bone microstructure and fracture frequency exists, and whether or not this is the product of association between the directions of physiological and traumatic forces.

Keywords: Mandibular condyle, micro-computed tomography, X-ray microtomography, diacapitular fracture, bone structure, anatomy

Introduction

Within mandibular fractures, the condyle is a commonly affected anatomical site[1,2], with the head, neck or base of the condyle potentially affected[3]. Diacapitular fractures (affecting the head) can be categorised clinically according to the feasibility of fixation treatment and whether or not dislocation and displacement occur[4], whether or not ramal height shortening and disc displacement occur[5], or based on the site of the fracture line and reduction in ramal height[6].

Fractures have been described according to where the centre of the fracture line locates on the condyle's mediolateral axis, relative either to the condyle's 'pole zone'[6] or its mediolateral axis[7]. The latter system features categories for the lateral (A), central (B) and medial (C) third of the condyle (Fig. 1), with a separate category (M) for comminuted fractures[7].

Having categorised according to this latter system, the frequency of fractures in 269 patients was: A 41.3%, B 30.1%, C 4.1% and M 21.6%, implying that the medial portion of the condyle is far less susceptible to fracture[7]. Both internal factors (*e.g.* dental state, osteoporosis) and external factors (*e.g.* site of impact, direction of force) affect mandibular fracture patterns[8]. However, the microstructure of the mandibular condyle has yet to be examined as an influence on fracture distribution.

As bone adapts to the loads it experiences[9], it is hypothesised that bone density correlates positively with demographic fracture susceptibility. Physiological loads and traumatic impacts are likely to be transmitted along similar trajectories. Less dense bone may be less likely to fracture (counterintuitively), as traumatic forces tend not to pass through it.

In this study, micro-computed tomography (μCT), otherwise known as X-ray microtomography, was used to quantitatively analyse trabecular bone density across the width of the mandibular condyle, to establish whether structural variation is associated with observed fracture patterns.

Materials and Methods

Scanning

Five cadaveric temporomandibular joint specimens were imaged in a Nikon XTEK H 225 ST MicroCT Scanner. Donors had provided written informed consent before decease for the use of their bodies for anatomical education and research, in compliance with the Human Tissue Act 2004.

Processing Scan Data

Thermo Scientific Amira Software (v2019.2) was used to produce three-dimensional reconstructions of trabecular bone from μCT data, through a process of digital subtraction.

Analysis of trabecular bone density was conducted in MicroView (v2.5.0-4145). Ten cylindrical virtual biopsies were taken, of diameter 50px, length 10px, at equal increments along the maximum mediolateral width of the condyle. Bone volume fraction (BVF) was calculated as the proportion of pixels above the threshold optical density of bone.

Statistical Analysis

Statistical analysis and data visualisation were conducted in R (v3.5.1). Parametric one-way analysis of variance (ANOVA) was justified by results of Shapiro-Wilks and Bartlett tests, and thereby used to explore differences in BVF between loci, followed by post-hoc pairwise t-tests with the Benjamin-Hochberg method applied to correct for multiple testing.

Results

Models of trabecular bone of the mandibular condyle (Fig. 2) facilitated visual appraisal of density distribution. Density appears greatest centrally, with less dense regions medially and laterally. Plotting BVF across standardised loci (Fig. 3) indicated uniform density across the lateral two-thirds of the condyle, with a decline medially. However, variation overlaps across the condyle, as medial decline is not consistent across individual sections.

No statistically significant difference in BVF between loci was indicated by ANOVA ($F(9) = 1.16$, $p = 0.346$) or post-hoc t-tests ($p_{min} = 0.352$), although there was a trend towards significance medially according to the p-values of the t-tests (Fig. 4). It is possible that a difference exists, but was masked by a lack of statistical power, such as due to a small sample size.

Discussion

Micro-computed tomography is an effective means of investigating bony microstructure, as it facilitates production of interactive three-dimensional models and precise analysis. These techniques enabled determination that trabecular bone density appears lower in the medial third of the mandibular condyle. However, differences were not found to be statistically significant; perhaps a consequence of insufficient sample size.

Further investigation is required to confirm whether a relationship exists between fracture prevalence and trabecular bone density. Lower density medially could reflect a decreased propensity for lines of force to run through the region, driving Wolffian adaptation[9]. This may underlie the lower relative incidence of fracture lines running medially[7], as traumatic forces may be conveyed along similar lines to physiological loads.

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Conflict of Interest Statement

The authors report no commercial or financial associations that might create conflict with information presented in the manuscript.

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Figure Legends

Fig. 1. Photograph of a mandibular condyle, divided into three along its maximal width. Letters correspond to condylar head fracture classification[3]. Classification depends on the location of the centre of the fracture line. A separate category, 'M', includes all comminuted fractures.

Fig. 2. Anterior view of trabecular bone of the left mandibular condyle. Patterning appears densest centrally, with a greater drop-off occurring medially than laterally.

Fig. 3. Box plots indicating bone volume fraction plotted against mediolateral positions (lateral to medial from left to right, respectively), with all individual readings plotted. Though a drop-off in density medially is observed on average, and in some sections, the pattern is not consistent, with considerable fluctuation across the condyle's width.

Fig. 4. Heat map indicating the p-values of post-hoc t-tests comparing bone volume fraction between mediolateral loci along the maximal width of the condyle. Though no results fell below the predefined significance level (0.05), there is a trend towards significance medially.

Fig. 1 - annotated condyle

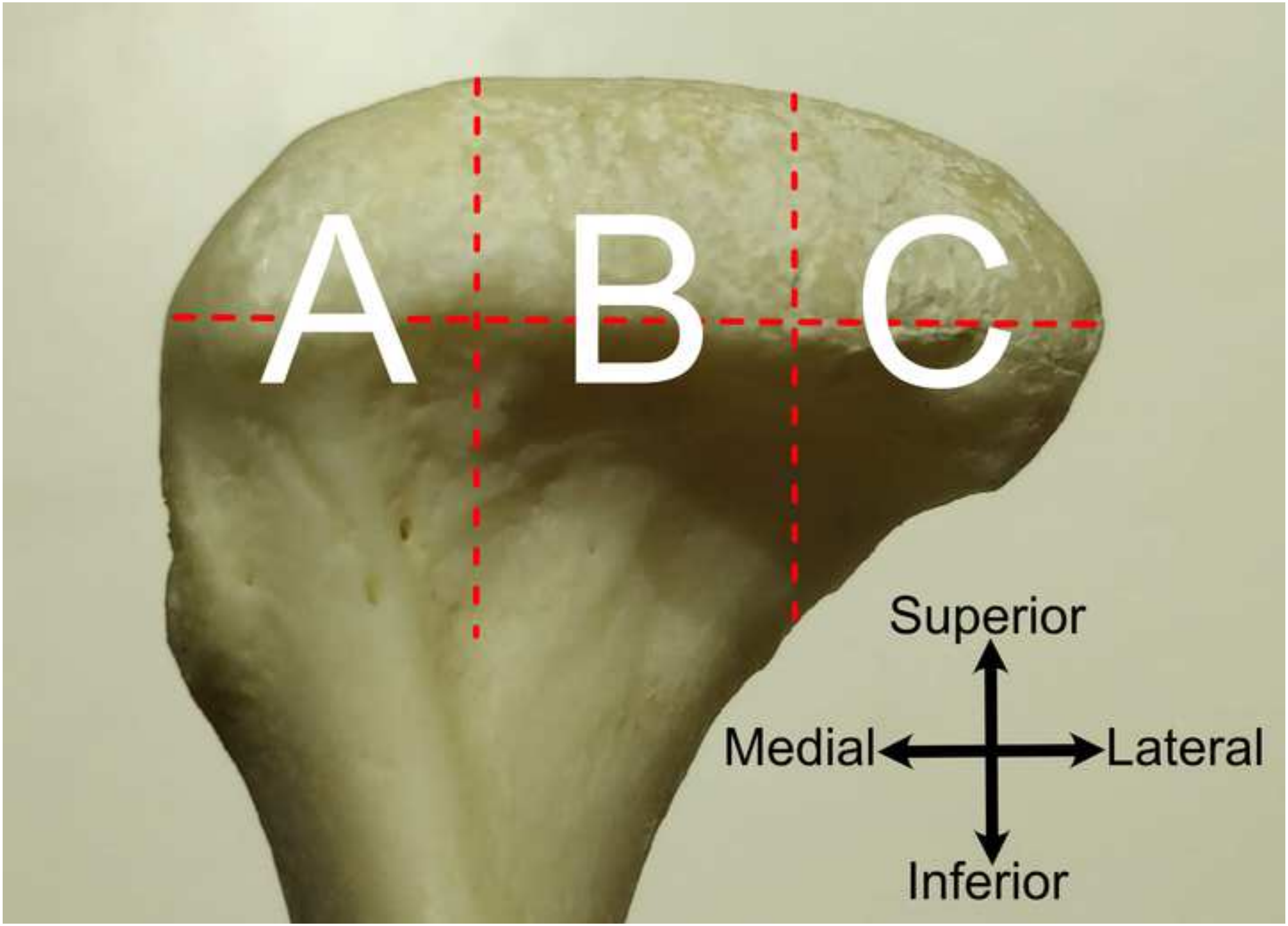

Fig. 2 - condylar trabecular bone

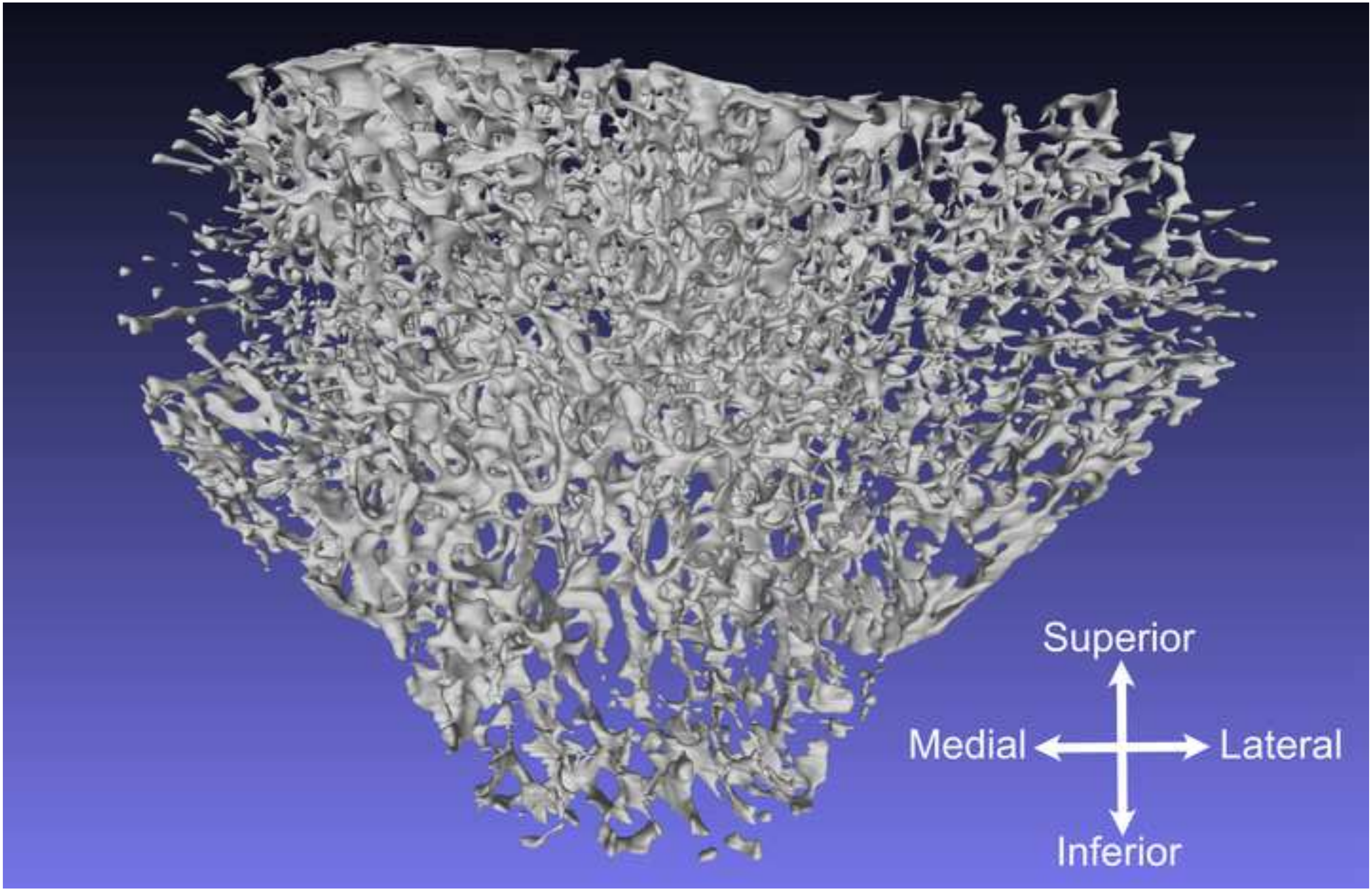

Fig. 3 - bone density across condylar width

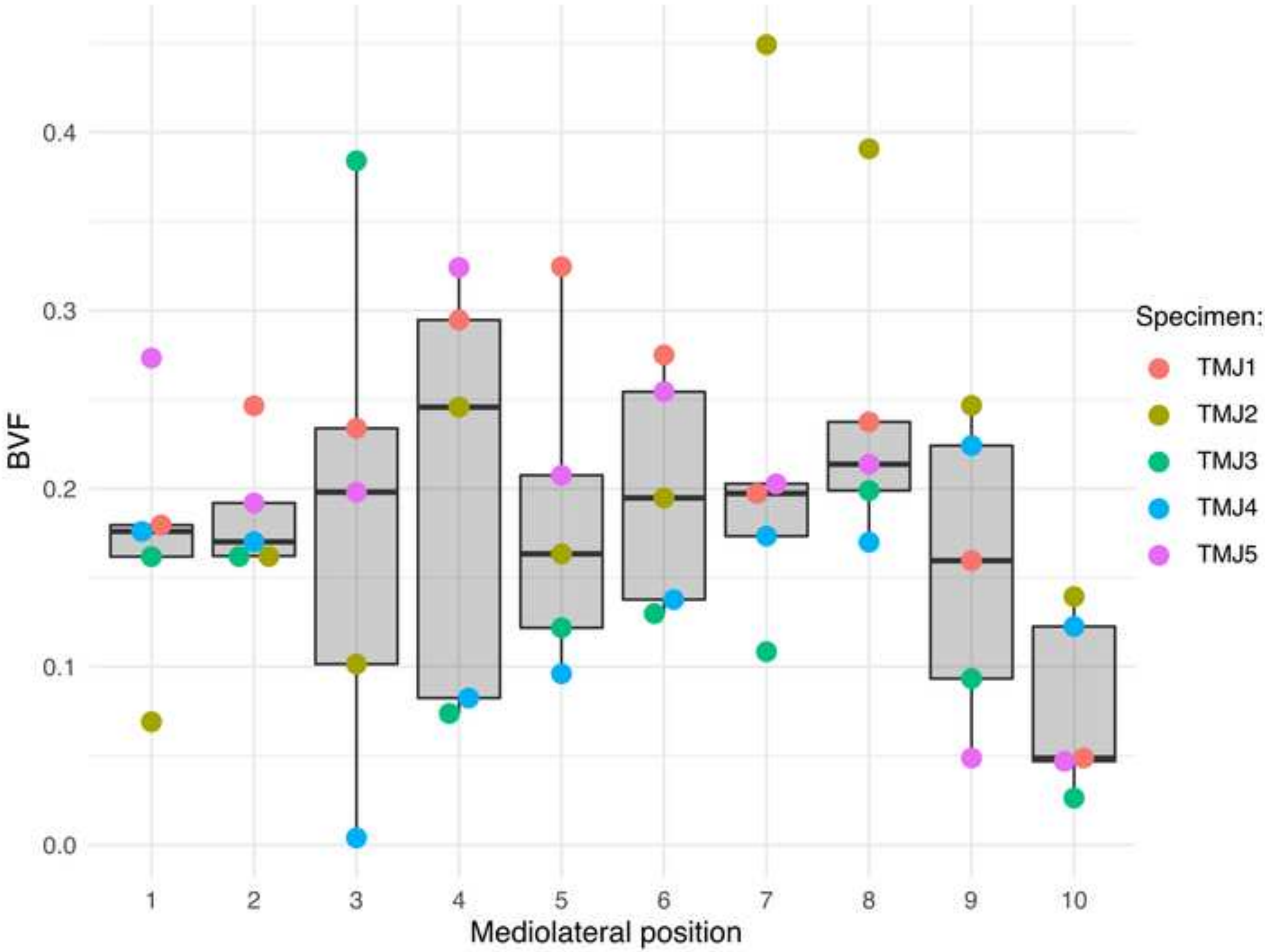

Fig. 4 - p values for t-tests comparing densities