EFFECTS OF CRACK PROPAGATION ON THE MECHANICAL BEHAVIOR OF TEMPOROMANDIBULAR JOINT DISCS

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Summary

This study investigates the fracture toughness of temporomandibular joint (TMJ) discs, focusing on crack orientation, sample thickness, and crack-to-width ratio. Forty ovine TMJ discs were tested, showing that AP-oriented discs had higher fracture toughness and resistance to crack propagation than ML-oriented discs. Longer cracks in ML discs required less force for propagation, and increasing thickness reduced toughness. These findings suggest considering fiber alignment in treatments.

Introduction

The temporomandibular joint (TMJ) disc is crucial for mandibular movement and stress absorption. This study investigates the fracture toughness of the TMJ disc, focusing on the impact of crack orientation, sample thickness, and crack-to-width ratio on its mechanical properties [1, 2].

Methods

Forty ovine TMJ discs were divided into two groups based on notch orientation: anteroposterior (AP) and mediolateral (ML). Fracture toughness was measured using the J-integral method. Cyclic tensile tests were performed, and statistical analysis was conducted using the Kruskal-Wallis. the equation for fracture toughness is:

$$J_{c(n)}=\frac{U_{F(n)}}{t\times\Delta c(n)} \qquad (1)$$

t represents the thickness of the sample and $\Delta c(n)$ represents the crack growth along the sample width during the n^{th} cycle. $U_{F(n)}$ determine the amount of energy dissipation caused by crack growth.

Results and Discussion

Anteroposterior (AP) vs. Mediolateral (ML): Fracture toughness in the AP direction was significantly higher than in the ML direction. The AP group showed higher resistance to crack propagation, with no crack growth observed in initial crack lengths ranging from 20% to 75%. In contrast, the ML group exhibited lower fracture toughness, with crack growth observed at various crack percentages.

Initial Crack Length and Crack Growth: The highest force observed in the AP group was approximately 88.2 N at 25% crack length, whereas the ML group showed a peak force of 12.5 N at 50% crack length. The ML group's highest percentage of cracks (77%) endured a maximum force of 9.86 N. Table 1 illustrates the maximum tensile force sustained by various cracks in different cycles in ML group.

The study shows TMJ discs have superior fracture resistance in the AP direction due to dense, perpendicular fiber bundles preventing crack propagation. This aligns with findings that high fiber density and perpendicular alignment limit cracks in the AP direction [3, 4]. Conversely, the ML orientation has lower fracture toughness as fibers align parallel to the crack, allowing easier propagation. Variations in fiber orientation affect fracture propagation during testing. In the AP group, dense central fibers and perpendicular crack orientation prevent primary crack propagation, resulting in infinite fracture toughness in this direction.

Additionally, the study found that longer initial cracks in the ML group required less force for propagation, highlighting the importance of fiber orientation in TMJ disc mechanics. Treatments and implants should consider this to enhance resilience. Furthermore, the study found that altering specimen width didn't affect maximum force or fracture toughness. Increasing thickness from 0.45 to 1.4 mm reduced fracture toughness from 37.45 to 1.36 KJ/m². These findings align with previous studies on soft tissues, highlighting the role of fiber orientation and density in mechanical properties [5].

Table 1. The maximum force before crack propagation and fracture toughness in ML direction

ML orientation					
Crack %	25% - 40%	40% - 50%	50% - 60%	60% - 70%	70% -
Max force (N)	-	9.01 ± 2.91	6.71 ± 2.96	5.40 ± 2.29	5.08 ± 2.75
J_{1c} (KJ/m^2)	-	5.56 ±2.81	13.69 ± 7.98	15.97 ± 9.7	16.61 ± 8.15

Conclusions

The study shows that TMJ discs oriented anteroposteriorly have superior fracture toughness due to dense fibers, while mediolateral orientation allows easier crack propagation and thickness reduces toughness

References

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