Approximating Surface Matrix Band for Dentists to Use in Patients

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Abstract

Fifty-three million people live with untreated tooth decay, labelling cavities as a silent epidemic. Cavities become more difficult to repair the longer they are left untreated, eventually leading to tooth loss [1]. Dental fillings remain the most common method of combating tooth decay, thus, it is essential that filling procedures are optimized. Current matrix bands used in these procedures fail to allow concurrent restoration of adjacent interproximal cavities. The team was tasked with designing a matrix band that can support the simultaneous reconstruction of two adjacent teeth with interproximal cavities. The final design mimics two adjacent matrix bands, but is designed with half the thickness of a regular matrix band to support the proper, flossable tooth contact within the interproximal space. The device incorporates a hole at the top for easy placement and removal as well as a space between each band side to allow the use of a wedge. Preliminary mechanical testing indicates that the 1008 steel used to fabricate our early prototypes provides similar structural support when compared to existing bands.

Motivation

Matrix bands are currently categorized as sectional or circumferential, meaning they contour around and provide support for part of the tooth (about half) or the whole tooth, respectively. However, neither provide support for 2 adjacent teeth, requiring the dentist to prep the matrix band and fill each tooth separately in the case of interproximal cavities. This results in an inconvenient and time consuming process. The team was tasked with filling this gap in the market by designing a matrix band that can fit in the interproximal space and provide support for both teeth. This would help simplify procedures making treatment more efficient, less costly, and more widely available.

Background

- Existing Matrix Bands
  - Tofflemire™ Matrix Band system (Circumferential)
  - Pro-Matrix Single Use Matrix Band (Circumferential)
  - The Trident V3 Ring and Wave-Wedge system (Sectional)

Figure 1: Tofflemire™ Matrix Band and retainer

Figure 2: Pro-Matrix Single Use Matrix Band

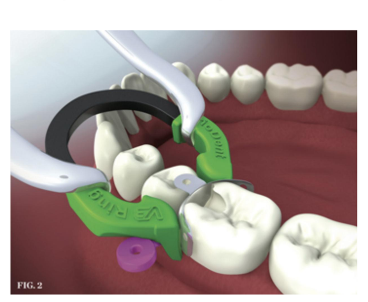

Figure 3: Triodent V3 Ring and Wave-Wedge System

- Dental Anatomy & Terminology
  - Interproximal - between adjacent teeth
  - Dead-soft - softest form of metal by means of processing and low carbon (interstitial) content [2]
  - Proper tooth contact and contour is essential for preventing bacteria and food from the interproximal space, which would lead to further decay
  - Dental Filling Materials
    - Composite resin (plastic and glass)
    - Ceramics/Porcelain
    - Silver Amalgam* or Gold

Design Criteria

- Matrix Band Size
  - 0.0254 - 0.0508 mm in thickness [3]
  - ~ 10 mm in height
    - Crown height ranges from 7.2 - 11.2 mm [4]
  - Shape around varying tooth perimeters
    - 22 - 45.8 mm [4]
- Matrix Band Material
  - Malleable, easy to shape
  - Non-toxic, non-reactive with filling materials
  - Mechanical properties similar to existing matrix bands
    - Tensile strength of dead-soft stainless steel: 260 - 340 MPa
    - Elastic modulus: 200 - 215 GPa [5]
- Matrix Band Performance
  - Single-use
  - Provide rigid contour to shape filling material
    - Prevent filling material from entering the gingiva
  - As simple placement/removal as existing matrix bands
  - Allow for shorter procedural time
    - < 30 minutes/tooth for client using current methods

Final Design

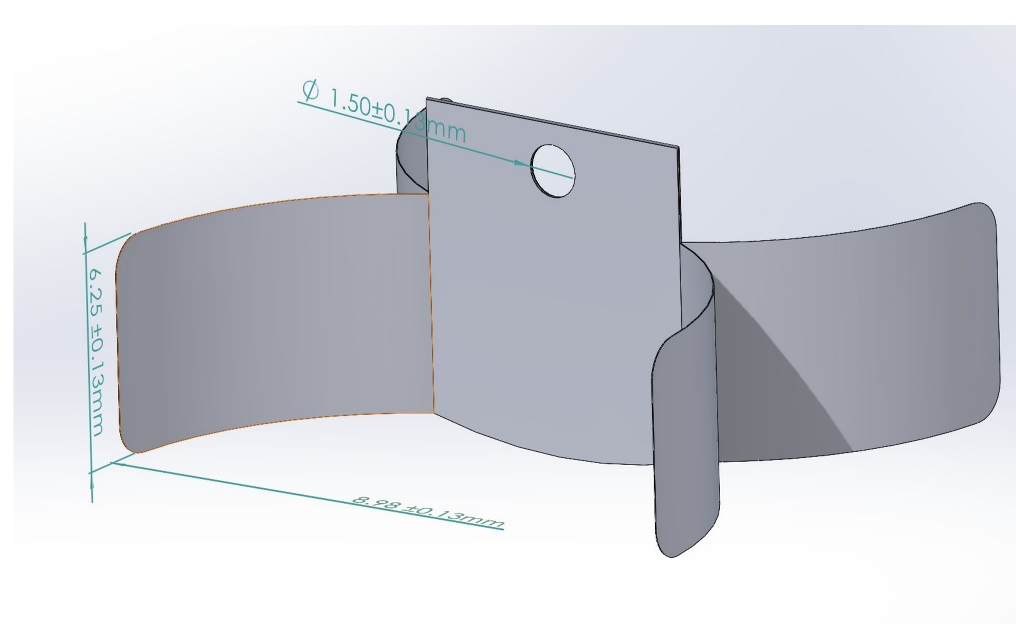

Figure 4: Dimensioned Solidworks model of final design

- Butterfly Design Dimensions
  - Thickness: 0.0254 mm
  - Height: 6.25 mm
- Features
  - Convex bottom edge
  - Tab with hole
  - Rounded corners
- Material
  - 1008-1010 Grade Stainless Steel
- Fabrication
  - Handmade using calipers and scissors
- Installation / Removal
  - Separate teeth
  - Carefully insert and stabilize with rings and wedge

Testing & Results

Testing was conducted to confirm that the 1008 steel alloy would be comparable to the stainless steel used on currently produced matrix bands in terms of mechanical properties.

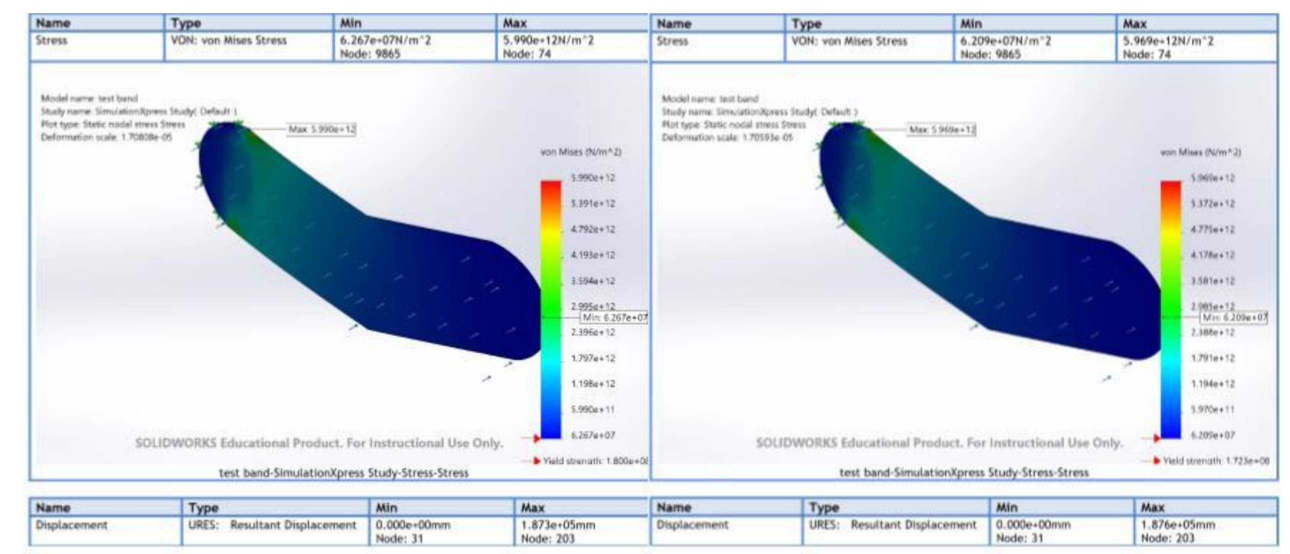

Figure 5: SolidWorks Simulink simulation results. Comparing two matrix bands of the same dimensions with varying material to determine differences in yield strength, von mises stress, and displacement

- Stress at 200N
  - Averaging 62.09 N/m^2 for generic stainless steel
  - Averaging 62.67 N/m^2 for 1008 steel alloy
- Yield Stress
  - 172.3 MPa for generic stainless steel
  - 180.0 MPa for 1008 steel alloy
- Steel compositions are comparable during stress test simulations
- Average Young's Modulus
  - Stainless Steel = 162.8 GPa
  - 1008 = 672.7 GPa

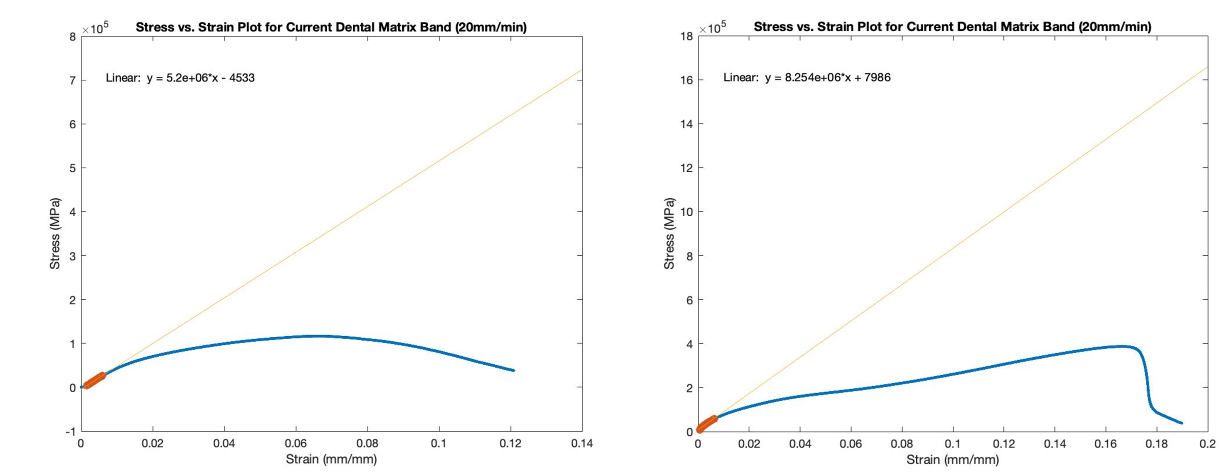

Figure 6: Plotted Stress-Strain curves from tensile testing on an MTS machine to determine Young's Modulus. Both runs above are with the 1008 steel alloy

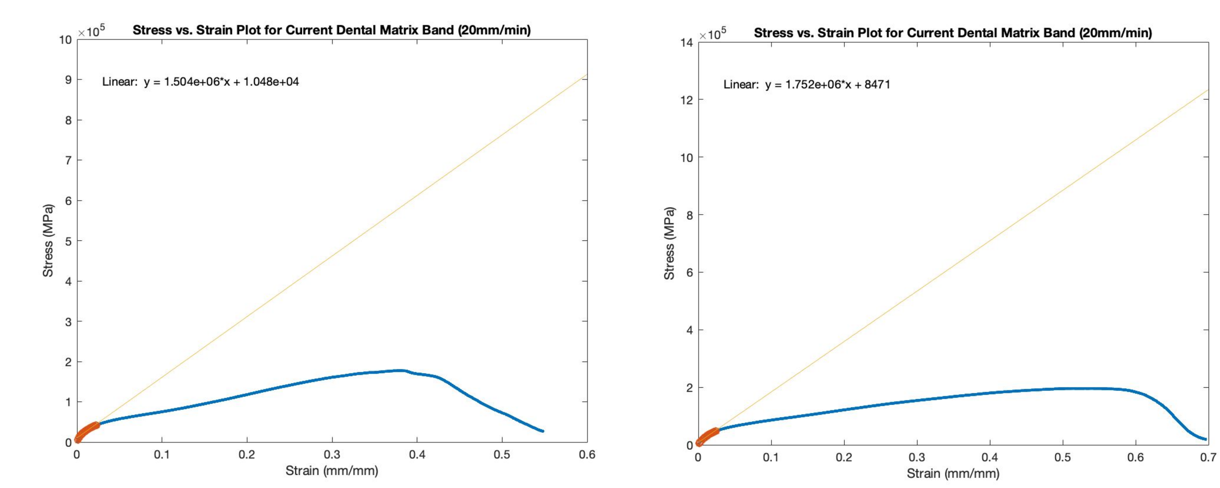

Figure 7: Plotted Stress-Strain curves from tensile testing on an MTS machine to determine Young's Modulus. Both runs above are with stainless steel

Figure 8: Sample being loaded into the MTS machine for tensile testing

Conclusions & Future Work

F-statistic value = 11.07739

P-value = 0.07964

Data Summary				
Groups	N	Mean	Std. Dev.	Std. Error
Group 1	2	672700000000	215950410974.3716	152700000000
Group 2	2	162800000000	17536248173.4264	12400000000

ANOVA Summary					
Source	Degrees of Freedom DF	Sum of Squares SS	Mean Square MS	F-Stat	P-Value
Between Groups	1	2.5999800999999998e+23	2.5999800999999998e+23	11.0774	0.0796
Within Groups	2	4.6942099999999996e+22	2.3471049999999998e+22		
Total:	3	3.0694011e+23			

Figure 9: One-Way ANOVA Test between ordered material and circumferential matrix band Young Modulus yielding p-value of .09

- Cannot conclude a significant difference between Young's Modulus
  - high P-Value
- Improve testing methods/strategies
  - Dog bone /taping to avoid slippage
- Potentially send design to third party manufacturer
- Qualitative testing
  - Conduct survey amongst dentist
  - Questionnaire to determine a functionality score

Acknowledgements & References

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