# Approximating Surface Matrix Band for Dentists to Use for 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 316L 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 Triodent V3 Ring and Wave-Wedge system (Sectional)

**Figure 1:** Tofflemire™ Matrix Band and retainer


**Figure 2:** Pro-Matrix Single Use Matrix Band

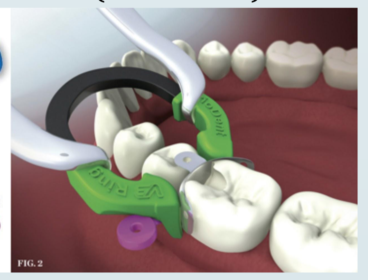


**Figure 3:** Triodent V3 Ring and Wave-Wedge System

- Dental Terminology
  - Interproximal - between adjacent teeth
  - Dead-soft - softest form of metal by means of processing and low carbon (interstitial) content [2]
- Global Market for Dental Fillings
  - 5.57 billion USD in 2019
  - 7.2% compounded annual growth rate to 2026 [3]

## Design Criteria

- Matrix Band Size
  - 0.0254 - 0.0508 mm in thickness [4]
  - ~ 5-6mm in in height
    - Crown height ranges from 7.2 - 11.2 mm including below gums [5]
  - Shape around varying tooth perimeters
    - 45.8mm for full circumference so about half [5]
- 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 [6]
- Matrix Band Performance
  - Single-use
  - Provide rigid contour to shape filling material
    - Prevent filling material from entering the gingiva
  - Allow for shorter procedural time
    - < 30 minutes/tooth for client using current method

## Design Evolution

- Developed butterfly design to bend around adjacent teeth
  - Initially had pinchers to help form the tooth

  Cut band as flat sheet and fold it over to make wings
  - Can use sheet metal
  - 5 Watt UV Laser Cutter
- Many sizing adjustments to fit into models correctly

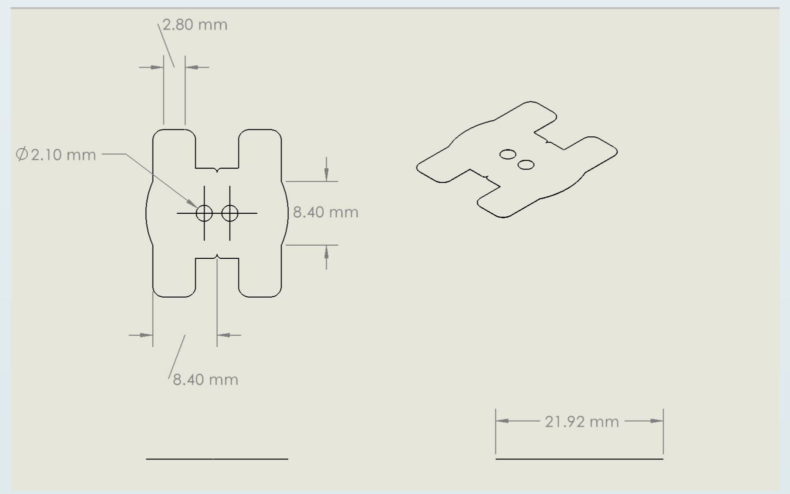



**Figure 4:** CAD drawing with dimensions of design that was exported as a dxf file for laser cutting

- Requires adhesive in the middle of the band
  - Contact point with tooth needs to be constant
  - Limiting wing movement
- Switched material to 316 Stainless Steel

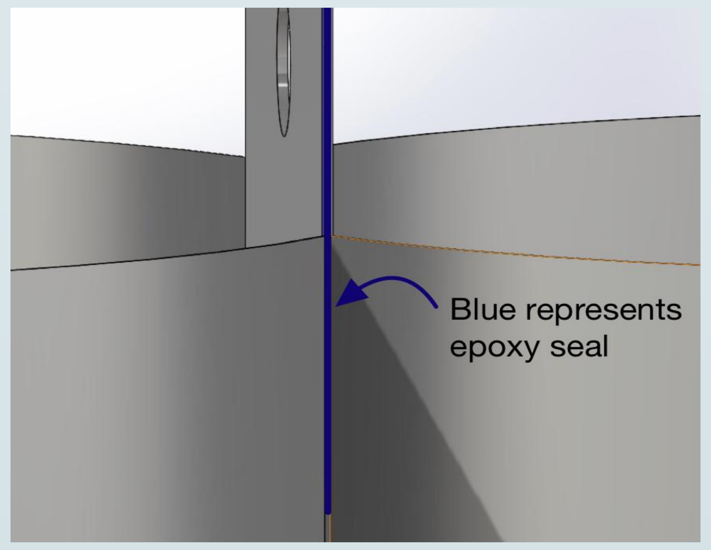



**Figure 5:** CAD model of butterfly design with blue highlight to show placement of epoxy

## Testing & Results

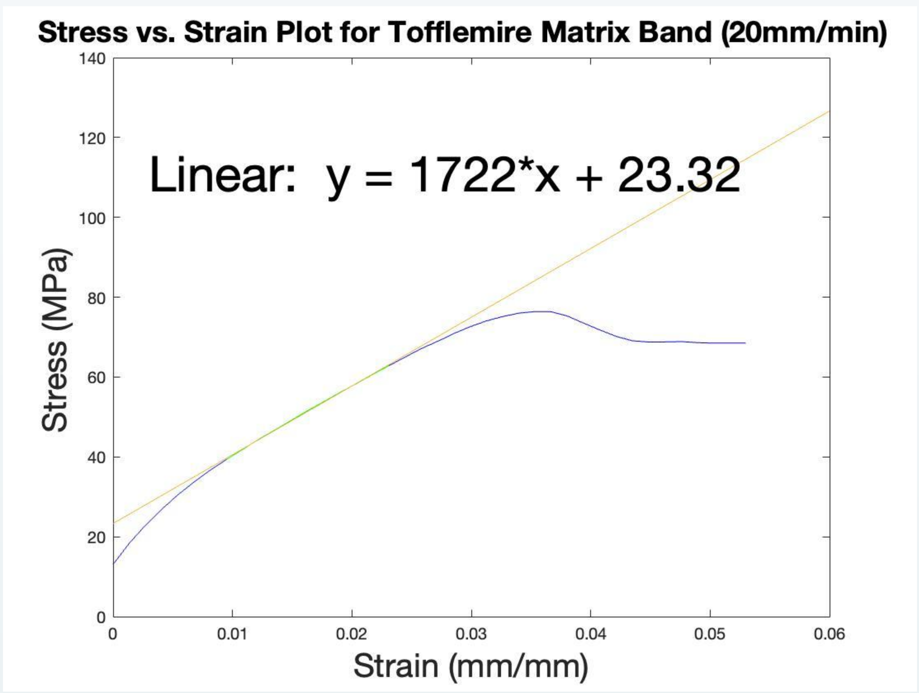



**Figure 6:** Plotted Stress-Strain curves from tensile testing of Tofflemire band material on an MTS machine to determine Young's Modulus. Average Young's Modulus value was 1.9 GPa.

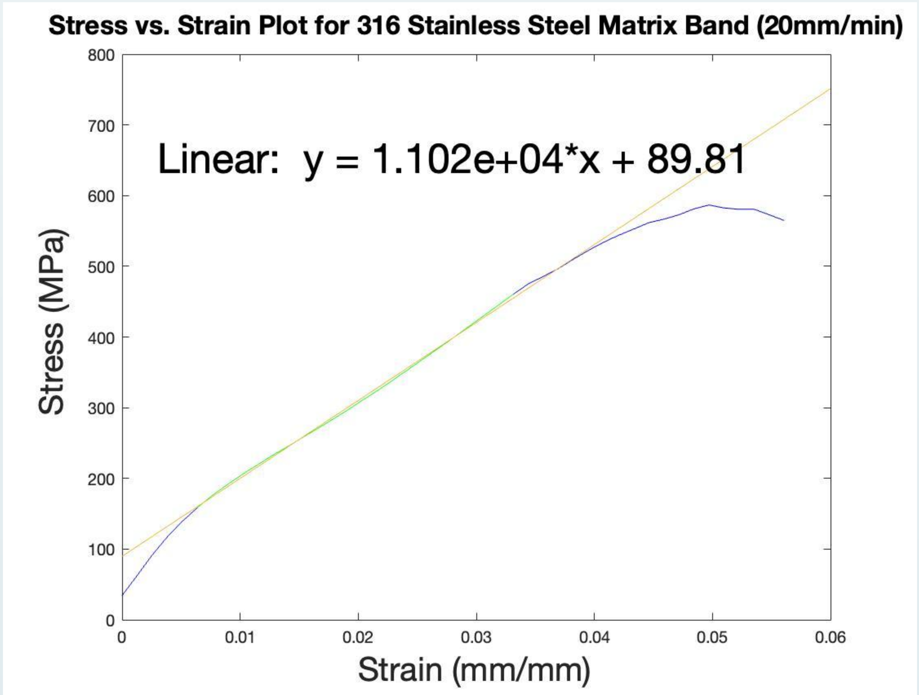



**Figure 7:** Plotted Stress-Strain curve from tensile testing of 316 Stainless Steel on an MTS machine to determine Young's Modulus. Average Young's Modulus value was 9.8 GPa

**Table 1:** One-Way ANOVA Test between 316 stainless steel and Tofflemire band stainless steel Young's Modulus yielding p-value of .0011. Values below are given in MPa

| Groups | N | Mean | Standard Deviation | Standard Error | F-Statistic | P-Value |
|---|---|---|---|---|---|---|
| Tofflemire Band Steel | 3 | 1884 | 206 | 119 | **69.25** | **0.0011** |
| 316 Steel | 3 | 9817 | 1638 | 946 | | |

**Table 2:** Results from survey taken by dentists with a 1 being the least favorable and 5 being the most favorable score in each category.

| Category | Dr. Brodek | Dr. Hazen | Dr. Tipple | Dr. Friend | Average |
|---|---|---|---|---|---|
| Protective Coverage | 5 | 5 | 5 | 5 | 5 |
| Ease of Placement | 5 | 4 | 5 | 2 | 4 |
| Compatibility | 5 | 4 | 5 | 2 | 4 |
| Material | 5 | 5 | 1 | 5 | 4 |
| Proper Placement | 3 | 4 | 2 | 5 | 3.5 |
| Proper Contact | 4 | 5 | 2 | 3 | 3.5 |
| Comparison- 1008/1010 | 5 | 5 | 4 | 1 | 3.75 |
| Comparison- Tofflemire | 4 | 4 | 2 | 3 | 3.25 |
| Procedure Time | 5 | 5 | 4 | 3 | 4.25 |
| | | | | | **3.92** |

## Conclusion

Key Design Features:

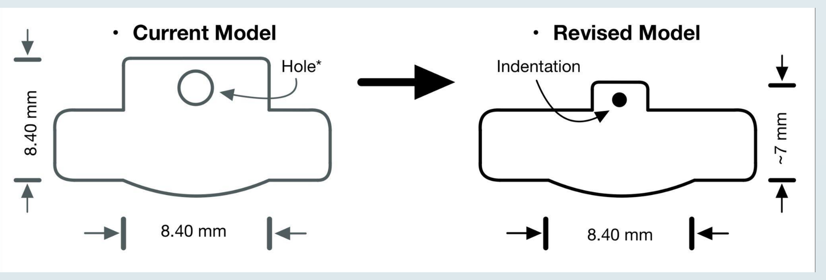
- Dual-wings for protection, support, and contour of adjacent teeth
- Thickness modification for proper tooth contact
- Tab for easy placement and removal
- Fold and bond fabrication for increases support and rigidity
- Convex, flared bottom edge for protection of gingiva and accommodation of wedges

Key Testing Takeaways:

- Pros:
  - Acceptable mechanical stiffness relative to existing bands
  - Sufficient protective coverage of the gingiva and oral cavity
  - Relatively easy placement and removal
  - Compatible with most existing tools and procedures
  - Reduces the time required for the procedure
- Cons:
  - Not as "dead-soft" or malleable as existing bands
  - May not provide as accurate of a tooth contour
  - Adhesive is not effective/Better without adhesive
  - Improper sizing, especially of the tab which hinders some functionality

## Future Work

1. Continue materials research and testing to find a more comparable metal, namely in regard to "dead-soft" malleability (Look into XRF and OES)
   a. 316L steel desired if available in proper thickness
2. Modify dimensions to shorten the height and width of the tab
   a. Consider shorter wing length
3. Consider reducing reflectivity of the metal for smoother laser cuts (surface treatment or coating)
4. Experiment with, and create more effective methods of fabrication (more accurate folds and curvature/contour)
5. Re-fabricate revised models
6. Modify testing protocols and criteria as needed
7. Test efficacy of revised prototypes and obtain feedback
8. Identify shortcomings and challenges → Iterate design process




## Acknowledgements & Works Cited

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