

A. Output generated with zero-shot prompting using o1 for a smart electronic toothbrush

1. Main Function

- Provide effective and efficient dental cleaning
- Integrate smart technology for enhanced user interaction

2. Functionally Determined Properties

- Vibrational or rotational cleaning mechanisms
- Adjustable intensity levels
- Wireless connectivity (Bluetooth, WiFi) for app integration

3. Operational Properties

3.1. Battery Life: Should last at least two weeks on a single charge with twice-daily usage

3.2. Usability: Easy to use by all age groups

3.3. Software: User-friendly app interface for tracking brushing habits

4. Service Life and Maintainability

- Minimum operational lifespan of 3 years under normal usage conditions
- Easily replaceable brush heads
- Simplified disassembly for battery replacement or recycling

5. Safety

- Electrical and mechanical safety compliant with consumer product standards
- Features to prevent over-brushing or gum damage

6. Ergonomic Properties

- Comfortable grip suitable for various hand sizes
- Balanced weight distribution to minimize wrist strain

7. Appearance and Design

- Modern, sleek design
- Available in multiple colors to appeal to different tastes
- Modular design for easy upgrade and customization
- Environmentally friendly materials and recyclable components

8. Laws and Standards

- Compliance with local and international regulations concerning health and safety
- Adherence to wireless communication standards

9. Economics

- Cost-effective production while maintaining high quality
- Competitive pricing strategy in the smart personal care market

B. Output generated with one-shot prompting using o1 for a smart electronic toothbrush

1. Main Function

Description

- Primary Purpose: Clean and maintain oral hygiene using smart technology.

Key Features

- Advanced brushing modes (e.g., whitening, gum care, sensitive)
- Real-time brushing feedback
- App connectivity for data logging and brushing habits analysis
- Automatic pressure sensor
- Timed brushing sessions
- Long battery life with fast charging

2. Functionally Determined Properties

Performance Requirements

- Power Output: 3.7 V 1500 mAh rechargeable battery
- Modes: Five modes (e.g., Clean, White, Polish, Gum Care, Sensitive)
- Brushing Speed: 30,000 to 40,000 strokes per minute
- Efficiency: 90–95 % plaque removal in clinical tests
- Capacity: 4-week usage per charge on a single full charge

Functionality

- Intelligent pressure sensor to avoid excessive force
- Bluetooth connectivity to sync with mobile apps
- Automatic timers and alerts for optimal brushing time
- Replaceable brush heads with wear indicators

3. Operational Properties

Operating Conditions

- Temperature Range: 10 °C – 40 °C ambient environment
- Humidity: 30 % to 85 % non-condensing moisture
- Water Resistance: IPX7 waterproof rating for safe use in wet environment

User Interaction

- Touchscreen display or LED indicators for mode selection
- Mechanical power and mode buttons
- Haptic feedback for alerts (vibration)
- Integration with mobile app via Bluetooth for personalized reports
- Audio alerts and visual indicators (LED lights) for low battery, mode changes and alerts

Support Systems

- Mobile app for detailed brushing data and reminders
- Wireless charging system
- Firmware updates via mobile app connectivity

4. Service Life and Maintainability

Expected Lifespan

- Operational Lifespan: 5 years under average usage conditions
- Service Intervals: Brush head replacement every 3 months; battery check every 2 years
- Maintainability: Brush head replacements, battery replacement and software updates

Common Pitfalls and Important Product Parts

- Core Modules: Motor assembly, battery, brush head, PCB with Bluetooth module
- Fault Tolerance: Maintain function with minor errors in connective parts due to modular design

- Redundancy: Backup power management system for data protection

End-of-Life Handling

- Recycling: Brush heads, battery and electronic components
- Refurbishing: Eligible for a refurbishing program for extended service lifecycle
- Disposal: Proper disposal channels for hazardous materials

Standardized Parts

- Use standardized rechargeable battery sizes and types (e.g., 18650 Li-ion)
- Standard charging cables (USB-C)
- Uniform brush head connectors across models

5. Safety

Fail-Safe Mechanisms

- Auto-shutoff if excessive pressure is detected to prevent gum injury
- Overcharge protection for battery

Protective Features

- Replaceable water seals to maintain waterproof rating
- User warnings (visual/audio) for excessive pressure, low battery, or operational errors

6. Ergonomic Properties

User Interface

- Touchscreen with icons for easy mode selection
- Voice-activated controls for hands-free operation

Accessibility

- Easy-to-remove battery cover and replaceable brush heads
- Modular design for easy part replacement

Physical Comfort

- Ergonomically designed handle with non-slip grip
- Brush angle designed to fit various mouth sizes comfortably

Dimensions

- Product Dimensions: 25 cm (height) x 3 cm (width)
- Weight: 250 grams
- Additional Space: 5 cm clearance for ventilation when charging

7. Appearance and Design

Aesthetic Design

- Sleek, contemporary design with smooth lines
- Color options in white, black and pastel shades
- Matte finish for a modern look

Finish and Materials

- High-quality ABS plastic with soft-touch rubber handle
- Stainless steel accents for durability
- Easy-to-clean surfaces

Visual and Auditory Feedback

- LED indicators for brushing mode and battery level
- Sound alerts for brushing duration and pressure warnings

8. Law and Standards

Regulatory Compliance

- Safety: Compliant with UL and CE safety standards
- Environmental: RoHS compliance for hazardous materials
- Wireless: FCC certification for Bluetooth components

Certifications

- CE mark for European markets

- FCC mark for US markets
- ISO 13485 for medical device quality management

Relevant Patents

- Patent for intelligent pressure sensor technology
- Patent for advanced motor mechanism ensuring silent operation

9. Economics

Pricing Strategy

- Budget: \$50–\$80
- Middle of the Market: \$100–\$150
- Premium: \$200–\$250

Alternative Revenue Strategies

- Subscription model for consumables (brush heads)
- Premium app features (personalized coaching, reminders)
- Extended warranty packages

C. Output generated with few-shot prompting using o1 for a smart electronic toothbrush

1. Main Function

1.1 Description

- Define the primary purpose of the product.
- Explain the specific problem the product solves or the need it fulfills.

1.2 Key Features

- Enumerate the main features that support the primary function.
- Highlight any innovative or distinguishing features.

2. Functionally Determined Properties

2.1 Performance Requirements

- Specify the performance metrics the product must meet (e.g., speed, capacity, accuracy).
- Include measurable targets and benchmarks.

2.2 Functionality

- Detail all functionalities, including core and secondary capabilities.
- Describe how the product should respond under different scenarios.

3. Operational Properties

3.1 Operating Conditions

- Define environmental and operational parameters (e.g., temperature, humidity, power supply).
- Identify any special conditions required for optimal performance.

3.2 User Interaction

- Outline the interaction processes between the user and the product.
- Define user levels (e.g., novice, advanced) and associated interfaces.

3.3 Support Systems

- List auxiliary systems required to support product operation (e.g., software updates, maintenance tools).
- Include dependency on external services or networks.

4. Service Life

4.1 Expected Lifespan

- Specify the designed lifespan of the product.
- Define parameters for usage frequency and conditions.

4.2 Common Pitfalls and Important Product Parts

- Identify components most prone to wear and tear.
- Highlight critical parts requiring special attention during design and use.

4.3 End-of-Life Handling

- Define recycling or disposal processes.
- Include considerations for environmental impact and user convenience.

4.4 Service Manuals

- Specify the required contents for user and maintenance manuals.
- Highlight troubleshooting guides and service procedures.

4.5 Standardized Parts

- List parts that should comply with industry standards for easy replacement.
- Include considerations for modularity and interchangeability.

5. Safety

5.1 Fail-Safe Mechanisms

- Detail mechanisms to prevent catastrophic failures.

- Include redundant systems and emergency shutdown features.

5.2 Protective Features

- Specify user protection measures (e.g., shielding, alarms).
- Include safeguards against misuse or accidental operation.

6. Ergonomic Properties

6.1 User Interface

- Define the layout and design of controls and displays.
- Ensure intuitive operation for the target user base.

6.2 Accessibility

- Include provisions for users with disabilities.
- Ensure compliance with accessibility standards (e.g., ADA, WCAG).

6.3 Physical Comfort

- Specify ergonomic design requirements for prolonged use.
- Include considerations for different body types and usage scenarios.

6.4 Visual and Auditory Feedback

- Define feedback mechanisms (e.g., lights, sounds) to confirm operations.
- Ensure feedback is clear and unambiguous.

6.5 Dimensions

- Provide guidelines for size, weight and portability.
- Ensure compatibility with intended environments.

7. Appearance and Design

7.1 Aesthetic Design

- Define design principles (e.g., sleek, minimalistic, bold).
- Align with target market preferences.

7.2 Finish and Materials

- Specify materials and finishes for durability and visual appeal.
- Include considerations for sustainability.

7.3 Branding

- Ensure alignment with the brand's identity.
- Include logo placement and packaging design.

8. Law and Standards

8.1 Regulatory Compliance

- List all legal requirements the product must adhere to.
- Include international, national and local regulations.

8.2 Certifications

- Identify necessary certifications (e.g., ISO, CE, UL).
- Define the process for obtaining and maintaining certifications.

8.3 Relevant Patents

- Check for existing patents that might affect product design.
- Include steps to secure intellectual property.

9. Economics

9.1 Pricing Strategy

- Define the pricing model (e.g., cost-plus, value-based).
- Include considerations for production costs and market positioning.

9.2 Alternative Revenue Strategies

- Identify potential revenue streams (e.g., subscriptions, add-ons).
- Include plans for product scalability and monetization.

D. Output generated with the tree-of-thought heuristic using o1 for a smart electronic toothbrush

Step 1: Define the Problem

Goal: Create a smart teeth-cleaning product that is effective, user-friendly, secure and compliant with relevant standards.

Step 2: Generate the Tree of Thoughts

Root Node: Key Requirements Categories

Branch 1: Functional Requirements

Branch 2: Performance Requirements

Branch 3: Usability Requirements

Branch 4: Reliability Requirements

Branch 5: Security Requirements

Branch 6: Compliance Requirements

Branch 7: Technical Specifications

Branch 8: Cost Requirements

Branch 9: Timeline Requirements

Each branch explores specific requirements with possible options for implementation.

Branch 1: Functional Requirements

- **Sub-node 1.1:** Cleaning Modes
 - Option A: Single mode for all users.
 - Option B: Multiple modes (e.g., sensitive, gum care, whitening). **(Chosen: Better personalization)**
- **Sub-node 1.2:** Smart Features
 - Option A: Pressure sensor to detect excessive brushing force.
 - Option B: Real-time feedback on coverage via app.
 - Option C: AI-driven personalization of brushing patterns. **(Chosen: Option B + C for innovation and feedback)**
- **Sub-node 1.3:** Additional Features
 - Option A: Built-in timer (e.g., 2 minutes).
 - Option B: Multi-purpose (e.g., tongue and gum cleaner). **(Chosen: Both for versatility)**
- **Outcome:** Functional requirements include multiple cleaning modes, real-time feedback with AI and additional features like a timer.

Branch 2: Performance Requirements

- **Sub-node 2.1:** Cleaning Efficacy
 - Option A: Vibrations at 20,000 strokes/minute.
 - Option B: Vibrations at 30,000+ strokes/minute. **(Chosen: Better cleaning efficacy)**
- **Sub-node 2.2:** Battery Life
 - Option A: 1-week battery life.
 - Option B: 10+ days battery life. **(Chosen: Option B to reduce user frustration)**
- **Sub-node 2.3:** Connectivity
 - Option A: Bluetooth 4.0.
 - Option B: Bluetooth 5.0 or higher for stability and speed. **(Chosen: Option B)**
- **Outcome:** High-frequency vibrations, extended battery life and Bluetooth 5.0.

Branch 3: Usability Requirements

- **Sub-node 3.1:** Interface

- Option A: Simple button controls.
- Option B: Touch-based interface. **(Chosen: Option A for simplicity and durability)**
- **Sub-node 3.2: Ergonomics**
 - Option A: Basic ergonomic handle.
 - Option B: Customizable grips for different hand sizes. **(Chosen: Option B for inclusivity)**
- **Sub-node 3.3: Accessibility**
 - Option A: Basic app interface.
 - Option B: App designed for accessibility (e.g., WCAG compliance). **(Chosen: Option B)**
- **Outcome:** Ergonomic handle, accessible app interface and simple button controls.

Branch 4: Reliability Requirements

- **Sub-node 4.1: Water Resistance**
 - Option A: IPX5 water resistance.
 - Option B: IPX7 or higher (can withstand immersion). **(Chosen: Option B for durability)**
- **Sub-node 4.2: Service Life**
 - Option A: 2 years.
 - Option B: 3 years or longer. **(Chosen: Option B for extended reliability)**
- **Sub-node 4.3: Error Detection**
 - Option A: Basic error indicators (e.g., lights).
 - Option B: Advanced notifications via app. **(Chosen: Option B)**
- **Outcome:** IPX7 water resistance, 3+ years of service life and advanced error detection.

Branch 5: Security Requirements

- **Sub-node 5.1: Data Encryption**
 - Option A: Basic encryption.
 - Option B: End-to-end encryption for data transfer. **(Chosen: Option B)**
- **Sub-node 5.2: User Authentication**
 - Option A: Password-protected app.
 - Option B: Biometric login. **(Chosen: Option B for convenience and security)**
- **Sub-node 5.3: Firmware Updates**
 - Option A: Manual updates.
 - Option B: Over-the-air updates. **(Chosen: Option B)**
- **Outcome:** End-to-end encryption, biometric authentication and OTA firmware updates.

Branch 6: Compliance Requirements

- **Sub-node 6.1: Safety Standards**
 - Option A: Basic electrical safety compliance.
 - Option B: FDA-approved materials and IEC compliance. **(Chosen: Option B)**
- **Sub-node 6.2: Data Privacy**
 - Option A: GDPR compliance.
 - Option B: GDPR + HIPAA (if storing sensitive health data). **(Chosen: Option B for broader compliance)**
- **Sub-node 6.3: Environmental Standards**
 - Option A: Basic recyclability.
 - Option B: Full RoHS compliance for hazardous material reduction. **(Chosen: Option B)**
- **Outcome:** Full compliance with FDA, GDPR, HIPAA and RoHS.

Branch 7: Technical Specifications

- **Sub-node 7.1: Sensors**

- Option A: Basic pressure sensors.
- Option B: Pressure + motion sensors for comprehensive data. **(Chosen: Option B)**
- **Sub-node 7.2: Brush Head Design**
 - Option A: Fixed brush head.
 - Option B: Interchangeable brush heads for versatility. **(Chosen: Option B)**
- **Outcome:** Pressure + motion sensors and interchangeable brush heads.

Branch 8: Cost Requirements

- **Sub-node 8.1: Target Price**
 - Option A: \$50–\$100.
 - Option B: \$100–\$150 (premium pricing). **(Chosen: Option B for premium positioning)**
- **Sub-node 8.2: Subscription Model**
 - Option A: No subscription.
 - Option B: Optional subscription for replacement heads. **(Chosen: Option B)**
- **Outcome:** Premium pricing with optional subscriptions.

Branch 9: Timeline Requirements

- **Sub-node 9.1: Development Phases**
 - Option A: 12-month timeline.
 - Option B: 18-month timeline for iterative development. **(Chosen: Option B)**
 - Outcome: 18-month timeline with clear milestones.

Step 3: Consolidate Outcomes

The final requirements, derived from the branches and selected options, form a comprehensive design specification for the smart teeth-cleaning product. By using the Tree of Thoughts method, the decision-making process is transparent and systematically considers multiple possibilities at each stage.

E. Output generated with the chain-of-thought heuristic using o1 for a smart electronic toothbrush

Requirements List

Smart Electronic Toothbrush

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Client: Hygiene Technology Association

| Nr. | D/ W | Requirements | Weight |
|----------|---------|---|--------|
| 1 | | Main Function | |
| 1.1 | D | The device must effectively remove plaque and debris from the user's teeth surfaces | 10 |
| 1.2 | D | The device must gently clean without causing gum irritation | 9 |
| 1.3 | W | The device may integrate with a smartphone application for personalized coaching | 7 |
| 2 | | Functionally Determined Properties | |
| 2.1 | | Performance Requirements | |
| 2.1.1 | D | Oscillation frequency $\geq 10,000$ strokes/min | 10 |
| 2.1.2 | D | Rotational speed adjustable in at least 3 distinct levels | 9 |
| 2.1.3 | D | Maintain cleaning efficiency for ≥ 2 years under normal usage | 8 |
| 2.2 | | Functionality | |
| 2.2.1 | D | Pressure sensor with feedback: reduce speed if applied force > 0.05 N | 10 |
| 2.2.2 | D | Timer function: 2-minute brushing cycle with 30-second interval alerts | 9 |
| 2.2.3 | W | Adaptive mode: brush automatically adjusts intensity based on user's brushing style | 9 |
| 3 | | Operational Properties | |
| 3.1 | | Operating Conditions | |
| 3.1.1 | D | Waterproof rating \geq IPX7 for safe operation in moist environments | 7 |
| 3.1.2 | D | Operating temperature range: 5 °C to 40 °C | 6 |
| 3.2 | | User Interaction | |
| 3.2.1 | W | LED indicators for mode, battery level and pressure feedback | 6 |
| 3.2.2 | W | App connectivity (Bluetooth) for usage data and personalized suggestions | 7 |
| 3.2.3 | D | Simple one-button interface to switch cleaning modes easily | 8 |
| 3.3 | | Support Systems | |
| 3.3.1 | W | Charging dock with inductive wireless charging to reduce cable clutter | 7 |
| 3.3.2 | W | Cloud-based analytics for usage patterns and remote guidance | 5 |
| 4 | | Service Life | |
| 4.1 | | Expected Lifespan | |
| 4.1.1 | D | Minimum designed lifespan of ≥ 3 years under normal use | 8 |
| 4.2 | | Common Pitfalls & Important Product Parts | |
| 4.2.1 | D | Replaceable brush head with wear indicators | 9 |
| 4.2.2 | W | Multiple brush head shapes for different dental needs | 5 |
| 4.3 | | End-of-Life Handling | |
| 4.3.1 | W | Use of recyclable or sustainable materials where possible | 5 |
| 4.4 | | Service Manuals | |

| | | | |
|----------|---|--|----|
| 4.4.1 | D | Easy-to-understand user manual including maintenance and cleaning guidelines | 7 |
| 4.5 | | Standardized Parts | |
| 4.5.1 | D | Standardized brush head mount compatible with future variants | 7 |
| 5 | | Safety | |
| 5.1 | | Fail-Safe Mechanisms | |
| 5.1.1 | D | Automatic shut-off if motor overheats | 8 |
| 5.1.2 | D | Electronic current limiter to prevent short circuits | 8 |
| 5.2 | | Protective Features | |
| 5.2.1 | D | BPA-free, FDA-approved materials for all mouth-contact parts | 9 |
| 5.2.2 | D | Rounded bristle tips to prevent gum damage | 9 |
| 6 | | Ergonomic Properties | |
| 6.1 | | User Interface | |
| 6.1.1 | D | Handle design ≤ 30 mm diameter for secure grip | 8 |
| 6.1.2 | W | LED display for mode/battery information | 5 |
| 6.2 | | Accessibility | |
| 6.2.1 | W | Voice guidance via app for visually impaired users | 4 |
| 6.2.2 | D | Large, tactile button for operation by users with limited dexterity | 8 |
| 6.3 | | Physical Comfort | |
| 6.3.1 | D | Weight ≤ 150 g for comfortable handling | 9 |
| 6.4 | | Visual and Auditory Feedback | |
| 6.4.1 | W | Gentle vibration cues to indicate quadrant changes | 7 |
| 6.5 | | Dimensions | |
| 6.5.1 | D | Brush head thickness ≤ 10 mm for easy intraoral positioning | 7 |
| 7 | | Appearance and Design | |
| 7.1 | | Aesthetic Design | |
| 7.1.1 | W | Modern, minimalistic aesthetic for market appeal | 4 |
| 7.2 | | Finish and Materials | |
| 7.2.1 | D | Durable, moisture-resistant handle surface | 6 |
| 7.3 | | Branding | |
| 7.3.1 | W | Discreet logo placement to maintain a clean look | 3 |
| 8 | | Law and Standards | |
| 8.1 | | Regulatory Compliance | |
| 8.1.1 | D | Compliance with CE, FCC and applicable medical device regulations | 10 |
| 8.2 | | Certifications | |
| 8.2.1 | W | Certification from recognized dental health organizations | 6 |
| 8.3 | | Relevant Patents | |
| 8.3.1 | W | Patent-pending or licensed technology for unique brush head design | 3 |
| 9 | | Economics | |
| 9.1 | | Pricing Strategy | |
| 9.1.1 | D | Competitive pricing within the mid-range market segment | 8 |
| 9.2 | | Alternative Revenue Strategies | |
| 9.2.1 | W | Subscription model for replacement brush heads | 6 |
| 9.2.2 | W | Premium app features (coaching, analytics) as optional paid add-ons | 4 |

Sum 300

F. Output generated with ensemble refinement using o1 for a smart electronic toothbrush

Step 1: Define the Objective

Objective: Use Ensemble Refinement to collaboratively refine and prioritize a requirements list for a smart toothbrush by synthesizing multiple reasoning paths and iteratively refining them.

Step 2: Create the CoT Prompt

The prompt should guide the model to reason step-by-step and provide detailed, diverse requirements in key categories (functionality, usability, safety and non-functional).

Example Prompt:

We are designing a smart toothbrush. Think step-by-step to identify requirements in the following categories:

1. Functionality
2. Usability
3. Safety
4. Non-functional requirements

For example:

Q: What requirements are needed for a smart water bottle?

A:

1. **Functionality:**

- Must track water intake accurately.
- Should provide reminders to drink water.

2. **Usability:**

- Should have a sleek, ergonomic design.
- Must be easy to clean and maintain.

3. **Safety:**

- must be BPA-free and durable.

4. **Non-functional Requirements:**

- Battery life should last at least a week.
- Should be compatible with major smartphone apps.

Now, consider the same categories for a smart toothbrush. Generate and refine the requirements list step-by-step.

Step 3: Generate Initial Requirements (Stage 1)

Generate diverse outputs with varying temperatures to capture a wide range of potential requirements.

Example Initial Outputs:

Output 1:

Functionality:

- Must clean teeth effectively with variable speed settings.
- Should track brushing habits and provide feedback.
- Could integrate with smart home devices.

Usability:

- Must have an ergonomic design.
- Should offer gamification for kids.

Safety:

- Materials must be non-toxic.
- Must comply with FDA and CE standards.

Non-functional Requirements:

- Battery life should last at least a week.
- Should support wireless charging.

Output 2:**Functionality:**

- Must remove plaque effectively.
- Should alert users about missed brushing zones.
- Could track long-term brushing data.

Usability:

- Must support voice guidance for accessibility.
- Should be travel-friendly.

Safety:

- Must be waterproof and shockproof.
- Should use child-safe materials.

Non-functional Requirements:

- Must have eco-friendly packaging.
- Should last at least a week on a single charge.

Output 3:**Functionality:**

- Must clean teeth effectively and detect improper brushing techniques.
- Should connect to a mobile app for personalized coaching.

Usability:

- Must include customizable settings for children and adults.
- Should feature multilingual app support.

Safety:

- Must prevent electric shocks and electromagnetic interference.
- Should comply with international safety regulations.

Non-functional Requirements:

- Should integrate with iOS and Android apps.
- Must support over-the-air (OTA) software updates.

Step 4: Refine the Outputs (Stage 2)

The second stage conditions the model with the concatenated outputs of Stage 1, synthesizing them into a more refined and coherent list.

Refinement Prompt:

Here are multiple proposed requirements for a smart toothbrush:

1. Must clean teeth effectively with variable speed settings.
2. Should track brushing habits and provide feedback.
3. Must support voice guidance for accessibility.
4. Should alert users about missed brushing zones.
5. Must have an ergonomic design.
6. Must be waterproof and shockproof.
7. Battery life should last at least a week.

Refine these requirements into a final, prioritized list with clear categories. Remove redundancies and ensure clarity.

Example Refined Output:**Functionality:**

- Must clean teeth effectively with adjustable speed settings.
- Should track brushing habits and provide real-time feedback via a mobile app.
- Should alert users about missed zones or improper techniques.
- Could track long-term data and integrate with health apps.

Usability:

- Must have an ergonomic design for all age groups.
- Should support voice guidance for accessibility.
- Should be travel-friendly with a compact design.

Safety:

- Materials must be non-toxic and child-safe.
- Must comply with FDA, CE and international safety standards.
- Must be waterproof and shockproof.

Non-functional Requirements:

- Battery life should last at least a week on a single charge.
 - Must support wireless charging and OTA software updates.
 - Should feature eco-friendly packaging.
-

Step 5: Iterate on Refinement

Repeat the refinement process multiple times (e.g., 2–3 iterations) to further synthesize and improve clarity. This helps the model refine reasoning paths and ensure no critical requirements are missed.

Step 6: Perform Majority Voting

From multiple refined outputs generated in Stage 2, use majority voting to finalize the requirements list. Requirements that consistently appear across refined iterations are included, ensuring robustness.

Final Requirements List:**1. Functional Requirements:**

- Must clean teeth effectively with adjustable speed settings.
- Should track brushing habits and provide real-time feedback via an app.
- Should alert users about missed zones or improper brushing techniques.
- Could integrate with health apps for long-term tracking.

2. Usability Requirements:

- Must have an ergonomic design suitable for all age groups.
- Should include voice guidance for accessibility.
- Should be compact and travel-friendly.

3. Safety Requirements:

- Must be made from non-toxic, child-safe materials.
- Must comply with FDA, CE and international safety standards.
- Must be waterproof and shockproof.

4. Non-functional Requirements:

- Battery life should last at least one week per charge.
- Must support wireless charging and OTA software updates.
- Should feature eco-friendly, recyclable packaging.

G. Output generated with choice shuffle ensemble using o1 for a smart electronic toothbrush

Step 1: Define the Objective

Objective: To create a comprehensive, prioritized list of requirements for a smart product for cleaning teeth, such as a smart toothbrush.

Step 2: Prepare the Prompt with CoT Reasoning

Design a CoT prompt that encourages the model to think step-by-step about requirements, exploring multiple plausible options for each aspect of the product.

Example Prompt:

We are designing a smart toothbrush. The goal is to identify requirements for such a product by considering functionality, usability, safety and other factors.

For each category, generate a list of plausible requirements, including:

- Basic requirements.
- Advanced requirements.
- Constraints or non-functional requirements.

For example:

1. Functionality:

- Basic: Brush teeth effectively.
- Advanced: Provide real-time feedback via an app.

2. Usability:

- Basic: Ergonomic design.
 - Advanced: Voice guidance for kids.
-

Step 3: Generate Multiple Requirement Lists

Using Choice Shuffle Ensembling, adjust the model's temperature to produce diverse outputs. Each generation should include a list of requirements with explanations.

Example Outputs:

Output 1:

Functionality:

- Must clean teeth effectively.
- Must have a built-in timer to track brushing duration.
- Should provide feedback on brushing quality via an app.

Usability:

- Must be easy to hold and operate for all age groups.
- Should integrate gamification features for kids.

Safety:

- non-toxic and durable.
- Non-Functional Requirements:
- Battery life should last at least a week per charge.

Output 2:

Functionality:

- Must clean teeth effectively with variable speed settings.
- Should offer real-time feedback on coverage and technique.
- Could integrate with smart home devices.

Usability:

- Handle should be customizable for children and adults.
- Should include multilingual app support.

Safety:

- Must be waterproof and shockproof.

Non-Functional Requirements:

- Should adhere to regulatory standards (e.g., FDA, CE).

Output 3:

Functionality:

- Should remove plaque efficiently.
- Should alert users about missed brushing zones.
- Could track user habits over time.

Usability:

- Should include a travel-friendly design.
- Must support voice guidance.

Safety:

- Must avoid electromagnetic interference.

Non-Functional Requirements:

- Should have eco-friendly, recyclable packaging.
-

Step 4: Perform Majority Voting

Group Similar Requirements:

Combine requirements with overlapping content from different outputs.

Example:

- "Must clean teeth effectively" appears in all outputs → Prioritize it.
- "Should provide real-time feedback via app" in two outputs → high priority.
- "Could integrate with smart home devices" appears once → Low priority.

Count Votes for Each Requirement:

- Identify the requirements with the most agreement across outputs.
 - Resolve conflicting requirements by analyzing the reasoning.
-

Step 5: Refine and Prioritize the Requirements List

Using the aggregated data, create a refined and prioritized list.

Final Requirements List:

Functional Requirements:

- Must clean teeth effectively with variable speed settings.
- Must provide feedback on brushing duration and quality.
- Should alert users about missed zones.

Usability Requirements:

- Must have an ergonomic, age-inclusive design.
- Should integrate gamification and multilingual app support.
- Should include voice guidance for accessibility.

Safety Requirements:

- Must be waterproof and non-toxic.
- Must comply with regulatory standards (e.g., FDA, CE).

Non-Functional Requirements:

- Battery life should last at least one week.
 - Packaging should be eco-friendly and recyclable.
-

Step 6: Validate the Requirements

Present the list to stakeholders (e.g., developers, designers, users).

Refine the list based on feedback and feasibility analysis.

H. Output generated with the self-consistency heuristic using o1 for a smart electronic toothbrush

Step 1: Define the Objective

Objective: Use Self-Consistency to create a comprehensive requirement list for a smart toothbrush by generating multiple reasoning paths and selecting consistent, high-priority requirements.

Step 2: Create a Few-Shot CoT Prompt

Design a prompt that encourages step-by-step reasoning to identify requirements across categories (e.g., functionality, usability, safety and non-functional aspects).

Example Prompt:

We are designing a smart toothbrush. Think step-by-step to identify key requirements in the following categories:

1. Functionality
2. Usability
3. Safety
4. Non-functional requirements

For example:

Q: What requirements are needed for a smart water bottle?

A:

1. **Functionality:**

- Must track water intake accurately.
- Should provide reminders to drink water.

2. **Usability:**

- Should have a sleek, ergonomic design.
- Must be easy to clean and maintain.

3. **Safety:**

- Materials must be BPA-free and durable.

4. **Non-functional:**

- Battery life should last at least a week.
- Should be compatible with major smartphone apps.

Now, consider the same categories for a smart toothbrush.

Step 3: Generate Multiple Requirement Lists

Use the prompt to generate diverse CoT reasoning paths by varying the model's temperature. Each reasoning path results in a list of requirements.

Example Outputs:

Output 1:

Functionality:

- Must clean teeth effectively.
- Should provide feedback on brushing quality via an app.
- Could detect and alert users about missed zones.

Usability:

- Must have an ergonomic design suitable for all age groups.
- Should support gamification for children.

Safety:

- Materials must be non-toxic.
- Should comply with FDA and CE safety standards.

Non-functional Requirements:

- Battery life should last at least a week.
- Should integrate with smart home systems.

Output 2:

Functionality:

- Must clean teeth effectively with variable speed settings.
- Should track brushing habits over time.
- Could provide real-time coaching during brushing.

Usability:

- Must include a travel-friendly design.
- Should offer voice guidance for accessibility.

Safety:

- Must be waterproof and shockproof.
- Should avoid electromagnetic interference.

Non-functional Requirements:

- Should be compatible with iOS and Android apps.
- Should use eco-friendly packaging.

Output 3:

Functionality:

- Should clean teeth effectively and remove plaque.
- Must alert users about incorrect brushing techniques.

Usability:

- Should feature customizable settings for children and adults.
- Must provide multilingual support in the app.

Safety:

- Must ensure durability and prevent electric shock.
- Should comply with international safety standards.

Non-functional Requirements:

- Should last a full week on a single charge.
- Must support software updates for new features.

Step 4: Use Majority Voting to Identify Consistent Requirements

Analyze the generated requirements to identify those that consistently appear across outputs.

Example Analysis:

Functionality:

- Must clean teeth effectively (Appears in all outputs → High Priority).
- Should provide feedback on brushing quality via an app (Appears in 2 outputs → Medium Priority).
- Could alert users about missed zones (Appears in 2 outputs → Medium Priority).

Usability:

- Must have an ergonomic design (Appears in all outputs → High Priority).
- Should support gamification for children (Appears in 1 output → Low Priority).
- Must include a travel-friendly design (Appears in 2 outputs → Medium Priority).

Safety:

- Materials must be non-toxic (Appears in all outputs → High Priority).
- Must comply with safety standards (FDA/CE) (Appears in all outputs → High Priority).

Non-functional Requirements:

- Battery life should last at least a week (Appears in all outputs → High Priority).
 - Should use eco-friendly packaging (Appears in 2 outputs → Medium Priority).
-

Step 5: Final Refined Requirements List

After majority voting, the final requirements list is:

Functional Requirements:

- Must clean teeth effectively.
- Should provide feedback on brushing quality via an app.
- Could alert users about missed zones.

Usability Requirements:

- Must have an ergonomic design for all age groups.
- Must include a travel-friendly design.
- Should offer voice guidance for accessibility.

Safety Requirements:

- Materials must be non-toxic.
- Must comply with safety standards (FDA, CE).
- Must ensure durability and prevent electric shock.

Non-functional Requirements:

- Battery life should last at least a week.
- Should use eco-friendly packaging.