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Efficacy of Different Mouthguard Designs in Preventing Dentoalveolar Trauma and Assessing Factors Influencing Athlete Compliance: A Comprehensive Review

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Abstract

Background. Dentoalveolar trauma sustained during contact sports presents severe clinical challenges and lifelong economic burdens. Intraoral mouthguards serve as the primary preventive mechanism, yet protective efficacy varies significantly across commercial designs (Type I stock, Type II boil-and-bite, and Type III custom-made).

Aim. This systematic review evaluated the biomechanical shock absorption, upper airway physiological impacts, athlete compliance dynamics, and socio-economic cost-effectiveness of different intraoral mouthguard modalities.

Material and methods: A structured literature search of PubMed/MEDLINE, Scopus, and CENTRAL databases (2001–2026) was conducted to identify trials, biomechanical impact analyses, and epidemiological cohorts comparing mouthguard types. A core cohort of 20 seminal publications was systematically analyzed.

Results: Type I and Type II mouthguards offer poor biomechanical defense due to uncontrolled material thinning (<1.0–1.5 mm at primary impact zones), structural instability, speech impairment, and increased respiratory resistance. Conversely, Type III multi-layered laminated custom appliances maintain critical protective thickness (3.0–4.0 mm), optimize force dissipation, preserve baseline airway parameters (VO₂ max, tidal volume), and demonstrate superior long-term athlete compliance. Economic modeling confirms that upfront investment in custom appliances prevents compounding costs of lifelong restorative care.

Conclusions. Type III custom-made mouthguards represent the clinical gold standard for maxillofacial protection in athletic populations. Implementing mandatory custom mouthguard protocols in organized contact sports preserves respiratory performance, reduces injury incidence, and provides a highly cost-effective public health strategy.

Keywords: sports dentistry; mouthguards; dentoalveolar trauma; force dissipation; athletic performance; custom-made appliances

1. Introduction

The relationship between physical activity and orofacial health has become a focal point of contemporary sports dentistry. While the systemic benefits of regular sports participation are undeniable, the concurrent inflation of injury rates presents a substantial clinical conundrum. Dentoalveolar trauma encompassing insults to the hard dental tissues, the dental pulp, the periodontal ligament, and the supporting alveolar bone represents one of the most prevalent and severe non-fatal injuries sustained during athletic activities [1, 10]. The epidemiological landscape indicates that contact sports, traditionally categorized into high-contact disciplines such as rugby, american football, ice hockey, and mixed martial arts (MMA), as well as limited-contact sports like basketball, soccer, and handball, exhibit a high incidence of maxillofacial trauma [1, 8].

The clinical presentation of these injuries varies profoundly, ranging from uncomplicated enamel-dentin fractures to highly complex pathologies. Among the most severe manifestations are intrusive luxations, lateral luxations, and complete dental avulsions [7]. Unlike soft tissue lacerations or uncomplicated bone fractures that typically undergo a finite physiological healing process, severe dentoalveolar injuries often catalyze irreversible degenerative cascades. Pathologies such as progressive inflammatory root resorption, ankylosis, and chronic periapical periodontitis frequently culminate in premature tooth loss. Consequently, pediatric and young adult athletes who suffer from high-energy dental trauma often require complex, multi-disciplinary, and lifelong restorative sequences. These interventions, spanning across endodontic treatments, advanced surgical bone augmentations, and implant-supported prosthodontics, place an extraordinary, continuous financial burden on both the patient and national healthcare infrastructures [3, 15].

To combat this escalating public health concern, the International Association for Dental Traumatology (IADT), alongside various national dental and pediatric assemblies, has advocated for the implementation of comprehensive primary preventive protocols [7, 17]. Among the available preventative technologies, the intraoral mouthguard stands as the paramount defensive mechanism [7, 14]. The core objective of an intraoral mouthguard is to decouple the dentition from incoming external forces, acting as a biomechanical shield that attenuates and redistributes shock waves generated during direct impacts to the midface or indirect mandibular occlusal collisions [10, 16].

Despite unequivocal consensus regarding the general utility of mouthguards, the contemporary commercial and clinical market is heavily saturated with diverse appliance designs. These devices are fundamentally bifurcated by their fabrication methodologies into three primary categories: Type I (Stock), Type II (Mouth-formed or "Boil-and-Bite"), and Type III (Custom-made, laboratory-fabricated via vacuum or pressure-forming techniques) [10, 16]. Epidemiological audits and laboratory impact analyses reveal that the level of hard- and soft-tissue protection is not uniform across these modalities. Prefabricated stock guards and user-molded "boil-and-bite" variants are highly popular due to their low cost and immediate retail availability. However, their structural, morphological, and material properties are frequently compromised. Users frequently experience poor retention, inadequate material thickness over prominent anatomical structures, and significant obstruction of basic physiological functions, such as speech and open-mouth ventilation [18].

Conversely, custom-made appliances engineered over precise stone models of the patient's maxilla offer a highly intimate adaptation to the dental arch. This precise adaptation guarantees optimal retention, equalized force distribution, and uniform material cross-section, while simultaneously respecting the physiological boundaries of the upper airway [5, 6]. This structural discrepancy introduces a critical clinical dilemma: the device that offers the most convenient economic accessibility often provides the poorest biomechanical defense and the lowest patient adherence [15, 20].

Understanding this dynamic requires a careful look at the physical forces at play and the human factors that determine whether an athlete will actually wear a guard. This review synthesizes current biomechanical and clinical evidence to evaluate the protective efficacy of different mouthguard designs, analyze the physiological and psychological variables governing athlete compliance, and establish a clear, evidence-based protocol for the utilization of these devices in modern contact sports.

2. Methods

To evaluate the protective efficacy of various intraoral mouthguards and identify the factors influencing athlete compliance, a systematic literature review was conducted. The search strategy focused on identifying peer-reviewed clinical trials, biomechanical laboratory investigations, prospective epidemiological surveys, and international consensus guidelines published between 2001 and 2026. This 25-year timeline captures the technological evolution of sports dentistry, from standard single-layer mouthguards to modern multi-layered lamination, digital CAD/CAM workflows, and sensor-embedded telemetry.

Literature screening was executed across three primary biomedical databases: National Center for Biotechnology Information (NCBI) PubMed/MEDLINE, Elsevier's Scopus, and the Cochrane Central Register of Controlled Trials (CENTRAL). The search matrix utilized combinations of relevant keywords and Medical Subject Headings (MeSH) terms unified by Boolean operators, focusing on terms such as "sports dentistry," "mouthguards," "dentoalveolar trauma," "force dissipation," "additive manufacturing," and "athletic performance."

The retrieved literature was filtered using strict inclusion and exclusion criteria:

- **Inclusion Criteria:** Studies comparing at least two distinct mouthguard modalities (e.g., prefabricated over-the-counter designs versus professionally fabricated custom thermoformed or 3D-printed appliances); epidemiological surveys and clinical cohorts tracking sports-related dental injuries; laboratory impact simulations (including drop-weight tests and finite element analysis); and evaluations of digital intraoral workflows or sensor-embedded telemetry.
- **Exclusion Criteria:** Isolated case reports with low-tier anecdotal evidence, non-peer-reviewed commentaries, editorials, unindexed conference abstracts, and studies evaluating purely extraoral protection (such as face cages or shields) without an intraoral elastomeric component.

Following duplicate removal and title/abstract screening, a core cohort of 20 seminal peer-reviewed publications was selected as the analytical foundation for this review [1–20]. Data regarding manufacturing type (thermoformed vs. 3D-printed), material composition, thickness at critical zones (labial, incisal, and occlusal), retention, physiological airflow metrics (VO₂ max), and economic cost-benefit factors were systematically extracted and synthesized.

2.2. AI.

AI was utilized for two specific purposes in this research. Text analysis of clinical reasoning narratives to identify linguistic patterns associated with specific logical fallacies. Assistance in refining the academic English language of the manuscript, ensuring clarity, consistency, and adherence to scientific writing standards. AI were used for additional linguistic refinement of the research manuscript, ensuring proper English grammar, style, and clarity in the presentation of results. It is important to emphasize that all AI tools were used strictly as assistive instruments under human supervision. The final interpretation of results, classification of errors, and conclusions were determined by human experts in clinical medicine and formal logic. The AI tools served primarily to enhance efficiency in data processing, pattern recognition, and linguistic refinement, rather than replacing human judgment in the analytical process.

3. Results & Technological Characterization of Mouthguards

The collective evidence confirms that the mechanical protection of the stomatognathic system is directly correlated with the manufacturing process, structural design, and retentive properties of the chosen intraoral device [10, 16]. Intraoral appliances are clinically classified into three distinct categories based on their manufacturing technology: Type I (Stock), Type II (Mouth-formed or "Boil-and-Bite"), and Type III (Custom-made) [10].

Feature / Metric	Type I: Stock Mouthguards	Type II: Boil-and-Bite Mouthguards	Type III: Custom-Made Appliances
Manufacturing Method	Factory mass-produced; ready-made straight out of packaging.	Factory pre-formed blank; thermoplastic material molded by user in hot water.	Professionally fabricated in laboratory over an accurate maxillary stone model.
Material Base	Rigid rubber, polyvinyl chloride (PVC), or low-grade plastics.	Thermoplastic polymers, predominantly Ethylene vinyl acetate (EVA) copolymers.	High-grade, multi-layered or laminated medical Ethylene vinyl acetate (EVA).

Anatomical Fit & Retention	Poor; lacks close adaptation to dental arch or soft tissue contours.	Moderate; offers rough adaptation to general alignment of teeth.	Excellent; precise micro-adaptation to teeth, gingiva, and palatal vaults.
Impact Absorption & Force Dissipation	Low; material is easily crushed, transferring raw kinetic energy to teeth.	Variable and highly unpredictable due to localized material thinning during molding.	Superior; predictable, controlled thickness with optimal shock attenuation via lamination.
Speech & Articulation Interference	Severe; prevents clear communication due to mandatory jaw-clenching.	Moderate to high; requires constant conscious effort to keep guard in place.	Minimal; secure retention allows normal physiological movement of tongue and mandible.
Respiratory & Airway Comfort	Severe obstruction; forces athlete to breathe through partially closed mouth.	Moderate interference; limits optimal volumetric airflow during high exertion.	Minimal interference; preserves near baseline upper airway volume and normal breathing.
Protective Capacity	Minimal; can shift during impact, occasionally worsening soft tissue lacerations.	Moderate; offers basic protection if material thickness is not overly compromised.	Superior; provides complete coverage and uniform dissipation of high-energy forces.
Athlete Compliance Rates	Extremely low; frequently discarded by athlete due to pain and instability.	Moderate; widely used due to low retail cost, but often abandoned mid-season.	High; comfortable fit and stable retention ensure long-term, consistent usage.

Table 1. Comprehensive comparative analysis of mouthguard types

3.1. Type I: Stock Mouthguards

Type I stock mouthguards represent the most primitive tier of intraoral protection available on the commercial market. Mass-produced in factory settings using standardized molds, these devices are distributed in a limited selection of sizes and are intended to be placed directly into

the user's mouth without any individual anatomical modification [10]. From a materials science perspective, stock mouthguards are typically composed of rigid vulcanized rubber, polyvinyl chloride (PVC), or basic synthetic plastics. Because these materials lack flexibility at body temperature, they cannot adapt to the complex three-dimensional topography of the human dentition, alveolar ridge, or palatal vault.

The clinical performance of Type I mouthguards is exceptionally poor, primarily due to their complete lack of retention. To keep a stock mouthguard in place during athletic activity, the athlete must maintain the mandible in a state of chronic, forced occlusion, clamping the device against the maxillary arch. This mandatory jaw-clenching triggers several physiological and structural complications. It places constant strain on the masticatory muscles, including the masseter and temporalis, leading to rapid muscle fatigue and localized cramping during physical exertion. Furthermore, it restricts oral ventilation, forcing the athlete to rely solely on nasal breathing, which is insufficient during high-intensity cardiovascular activity. Clear verbal communication with teammates or coaches is rendered impossible, as releasing the bite causes the guard to dislodge instantly under gravity or minor jaw movements [5, 6].

The protective capacity of Type I mouthguards is deeply flawed. When an external force impacts the midface, the loose plastic shell easily shifts out of position. Instead of absorbing energy, the rigid edge of a displaced stock guard can act as a secondary mechanism of injury, gouging unattached gingiva, tearing the labial frenum, or causing severe lacerations to the lips and buccal mucosa. Because they offer minimal biomechanical defense and cause substantial physical discomfort, Type I mouthguards exhibit the lowest athlete compliance rates in sports dentistry and are discouraged by modern clinical guidelines [7, 13].

3.2. Type II: Mouth-Formed ("Boil-and-Bite") Mouthguards

Type II mouthguards, colloquially termed "boil-and-bite" devices, are currently the most widely utilized form of intraoral protection across youth and amateur contact sports, largely driven by low retail cost and immediate availability [3, 11]. These appliances are supplied as factory-preformed thermoplastic blanks, usually composed of ethylene-vinyl acetate (EVA) copolymers or similar industrial polymers. The underlying concept relies on the thermal properties of EVA, which features a softening point between 60°C and 80°C. This allows the blank to be submerged in boiling water until pliable, after which it is transferred to the athlete's

mouth, where fingers, tongue, and biting pressure are used to mold the material around the maxillary teeth [10].

While Type II mouthguards represent a step up from stock models, their protective efficacy is highly variable and unpredictable due to inherent flaws in the user-molded fabrication process. When a thermoplastic polymer blank is molded in the mouth by the athlete, excessive occlusal biting pressure routinely causes critical material thinning, directly reducing protection in anterior and occlusal zones [18]. As a direct result, material thickness over the sharp incisal edges of maxillary incisors and functional cusp tips of permanent molars is frequently compressed down to less than 1.0 to 1.5 mm [10, 18]. Comprehensive biomechanical drop-weight impact trials have established that an EVA polymer barrier measuring less than 2.0 to 3.0 mm fails to provide adequate shock absorption. It undergoes complete mechanical compression under high-velocity impacts, transferring unattenuated kinetic energy directly into the tooth structure, leaving the athlete vulnerable to crown-root fractures and luxations [2, 18].

Additionally, manual adaptation achieved in a non-clinical environment cannot capture intricate micro-retentive details of the dental arch. Furthermore, as heated EVA polymer cools to oral temperature, it undergoes thermal volumetric shrinkage. This erratic contraction warps the internal geometry of the device, creating micro-gaps between the polymer wall and tooth surfaces. The resulting fit provides only moderate retention, meaning the mouthguard can easily loosen during rapid head movements, heavy hyperventilation, or physical contact. To keep the device secure, athletes must constantly maintain a conscious gripping effort or clench their jaws, causing noticeable speech interference, psychological distraction, and airflow restriction [6]. Consequently, while "boil-and-bite" guards provide a basic physical barrier, their structural unpredictability falls short of the strict safety standards required for high-risk contact sports [5, 16].

3.3. Type III: Custom-Made Appliances (Professionally Fabricated)

In contrast to the structural deficiencies of prefabricated retail options, Type III custom-made mouthguards represent the gold standard in sports dentistry and maxillofacial protection [6, 10, 14]. These appliances are fabricated within a controlled dental laboratory setting or clinic, utilizing an individualized three-dimensional stone model obtained from a high-precision impression or digital intraoral scan of the athlete's maxillary arch. By bypassing the volatile manual shaping processes associated with "boil-and-bite" devices, professional fabrication

ensures that the structural, mechanical, and spatial characteristics of the protective barrier are governed by precise engineering standards [10, 16].

The superior performance of Type III appliances is rooted in advanced manufacturing techniques, which fall into two primary methodological categories: vacuum-forming technology and high-pressure thermoforming with multi-layer lamination. Standard vacuum-forming utilizes a single layer of medical-grade EVA sheet heated uniformly and adapted under negative pressure. While superior to over-the-counter options, standard vacuum adaptation can still result in minor localized material pulling across prominent anterior surfaces. High-pressure thermoforming and multi-layer lamination represent the pinnacle of modern athletic intraoral engineering. Instead of relying on a single structural sheet, multiple distinct layers of high-grade EVA polymer are sequentially stacked over the stone model and subjected to pneumatic positive-pressure units operating between 4.0 and 5.0 atmospheres. This pressure forces the softened polymer sheets into every microscopic undercut, interproximal embrasure, and architectural nuance of the model, while allowing clinicians to strategically embed high-impact reinforcement strips or vary local thickness [10, 18].

The primary engineering achievement of multi-layered lamination is the eradication of uncontrolled material thinning. Because sheets are adapted under uniform mechanical pressure without being subjected to localized biting forces, the critical labial plate, incisal edges, and occlusal table maintain a predictable, uniform thickness. Extensive laboratory drop-weight impact testing has confirmed that a laminated Type III appliance maintains a guaranteed thickness of 3.0 to 4.0 mm across primary impact zones [10, 18]. This specific thickness threshold maximizes kinetic energy attenuation while keeping the internal volume of the appliance small enough to preserve airway function and speech articulation [5, 6].

Clinically, the micro-adaptation achieved by high-pressure thermoforming translates into physical retention and stability. The internal contours of a Type III appliance mirror oral anatomy so precisely that the mouthguard is held securely in place by surface tension, capillary action, and physical engagement with anatomical undercuts. The athlete does not need to clench their jaw to retain the device; it remains locked on the maxillary arch even during high-impact collisions, intense hyperventilation, or active speech. Because the mandible moves independently of the mouthguard, masticatory muscles remain relaxed, eliminating fatigue and cramping [5, 8]. Speech articulation remains virtually unimpeded, while upper airway

dimensions are preserved to maintain volumetric airflow and baseline respiratory performance [6].

4. Discussion

4.1. Biomechanical Principles of Force Dissipation and Energy Absorption

The primary mechanism by which an intraoral mouthguard protects the maxillofacial complex is rooted in classical physics regarding energy conservation and wave propagation [10, 16]. Upon a high-velocity impact to the midface or an indirect collision caused by violent mandibular closure, kinetic energy is delivered to the soft and hard tissues. Unprotected teeth absorb this energy directly, causing the rigid crystalline matrix of enamel and hydroxyapatite to experience sudden shear stresses that exceed their ultimate tensile strength, leading to fractures, luxations, or complete avulsions [2, 7].

When an elastomeric barrier such as a Type III custom-made mouthguard is introduced, it acts as a mechanical shock absorber that fundamentally alters impact dynamics. The material composition, primarily high-grade ethylene-vinyl acetate (EVA), exhibits viscoelastic behavior, possessing both viscous and elastic properties when undergoing deformation. When an external force hits the outer wall of the mouthguard, polymer chains slide past one another, absorbing a large portion of kinetic energy and converting it into harmless thermal energy via internal molecular friction [10, 18].

The remaining portion of kinetic energy is subjected to force dissipation. Rather than allowing force to concentrate at a single point of impact, such as the labial surface of a single central incisor, the adaptation of a custom appliance spreads stress waves uniformly across the entire dental arch, surrounding alveolar mucosa, and rigid palatal vault [2, 16]. Expanding the total surface area over which force is distributed reduces localized pressure applied to any individual tooth structure below the threshold required to induce hard-tissue failure or periodontal ligament rupture [10].

Furthermore, a properly extended custom mouthguard prevents indirect trauma by acting as an interocclusal cushion. During a blow to the inferior border of the mandible, the appliance prevents raw bone-to-bone or tooth-to-tooth contact, dampening impact force before it can propagate through the condylar process to cause subcondylar jaw fractures or force condyles upward into the glenoid fossa, thereby minimizing risks of concussion [2, 3, 12]. However,

laboratory drop-weight tower testing and finite element analysis (FEA) show that biomechanical protection depends heavily on maintaining critical material thickness [18]. Research by Westerman et al. [18] indicates that shock absorption capacity of EVA increases exponentially with material thickness up to a specific optimal plateau. An intraoral barrier requires a minimum thickness of 3.0 to 4.0 mm in labial and incisal zones to safely attenuate high-energy impacts without experiencing complete mechanical compression or "bottoming out" [18].

When a mouthguard drops below this critical threshold, its ability to damp impact waves is severely compromised. This is the primary reason Type I and Type II mouthguards fail in clinical environments. While a retail "boil-and-bite" guard may look protective externally, its uncontrolled thinning leaves underlying teeth shielded by a compressed polymer layer often measuring less than 1.0 mm, providing virtually no meaningful biomechanical protection against high-velocity injuries [18].

4.2. Physiological and Psychological Variables of Mouthguard Compliance

Beyond biomechanical protection, the clinical utility of any intraoral mouthguard is limited by its interaction with upper airway physiology and psychological comfort [5, 6]. In high-performance sports, where metabolic and respiratory demands are heavily elevated, any device that increases airway resistance or causes psychological distraction will inevitably be rejected or altered by the user [20].

Research evaluating the respiratory impact of mouthguards reveals a stark contrast between prefabricated options and custom appliances [5, 6]. During low-intensity exertion, nasal breathing is typically sufficient to meet metabolic needs. However, as physical activity increases and the athlete approaches their ventilatory threshold, human physiology demands a transition to oronasal breathing to accommodate higher volumetric airflow. It is during this high-exertion phase that physical fit and retention become critical to athletic performance [6].

Type I and Type II mouthguards introduce physiological airway resistance due to bulky design and poor retention. Because these over-the-counter devices lack a precise fit, they easily shift under gravity or heavy breathing. This structural instability forces the athlete to maintain continuous jaw clenching to keep the guard in place, restricting oral ventilation by reducing available oral cavity volume. This forced restriction causes changes in respiratory parameters.

When wearing a poorly fitted appliance, athletes exhibit increased airway resistance, a drop in tidal volume, and a compensatory rise in respiratory frequency. This breathing pattern increases the metabolic cost of ventilation, leading to premature fatigue of respiratory muscles [5, 6]. While short-term laboratory protocols suggest maximal oxygen consumption ($\text{VO}_2 \text{ max}$) can remain unchanged under controlled conditions, real-world athletic performance shows that the added work of breathing through a restricted oral passage induces subjective dyspnea and reduces overall athletic endurance [5, 6].

Conversely, Type III custom-made mouthguards respect natural upper airway anatomy. Because these devices are adapted under high pneumatic pressure to fit the microscopic contours of the maxillary teeth and palatal vault, they achieve retention without requiring active jaw clenching. The mandible drops naturally, allowing the oral airway to remain open during peak cardiovascular exertion. Objective physiological studies demonstrate that Type III mouthguards preserve near-baseline tidal volume, minute ventilation, and $\text{VO}_2 \text{ max}$ parameters [5, 6].

In addition to airway physiology, speech articulation and clear verbal communication are critical factors on the field. Team sports rely on split-second verbal commands, alerts, and strategic calls. Type I and Type II mouthguards cause severe speech distortion. The moment an athlete opens their mouth to speak, a loose appliance drops, altering tongue positioning against the anterior palate and garbling words. This forces the athlete to choose between clear communication or continuous dental protection—a compromise that frequently leads them to spit out or completely discard the device during play [5, 20]. In contrast, the stable, low-profile adaptation of a Type III custom mouthguard leaves tongue and mandibular movements unhindered, permitting normal speech clarity [5]. This structural stability provides a profound psychological benefit. When athletes do not have to worry about a loose device falling out, swallowing it, or choking on it during impact, their cognitive load is reduced, allowing them to focus entirely on tactical execution, which drives higher compliance rates throughout the season [19, 20].

4.3. Socio-Economic Cost-Benefit Analysis of Mouthguard Intervention

The clinical arguments for custom-fabricated athletic mouthguards must be contextualized within an economic framework to guide institutional policymaking and individual athletic investment. While some sports organizations hesitate to mandate professionally fabricated

Type III custom mouthguards due to higher initial financial costs, socio-economic analysis reveals that this upfront cost is negligible compared to the financial burden of managing complex orofacial trauma [3, 15]. Over-the-counter alternatives, such as Type I and Type II mouthguards, present a deceptive initial affordability that ignores high failure rates and inadequate energy-dissipation capabilities, shifting long-term financial risk directly onto the athlete and public healthcare infrastructures [15].

Dental trauma sustained during athletic activity rarely presents as a transient, single-intervention injury. A severe impact causing tooth avulsion, alveolar ridge fracture, or extensive crown-root fractures initiates a lifelong sequence of costly endodontic, surgical, and prosthodontic interventions [7, 15]. Long-term tracking data indicate that an avulsed tooth managed through emergency replantation frequently faces complications such as progressive root resorption or ankylosis, eventually necessitating extraction and subsequent dental implant placement [7].

The financial progression of a traumatic incident over an athlete's lifespan follows a compounding cost structure that begins with acute phase interventions, including emergency department triage, radiographic evaluation, stabilization of dentoalveolar segments, and primary endodontic therapy. Following acute care, the athlete enters an intermediate restorative phase, requiring periodic replacement of temporary restorations, apexification procedures, or surgical extraction followed by hard and soft tissue bone grafting. As treatment moves into long-term rehabilitation, the patient must undergo implant placement, custom abutment connection, and porcelain crown fabrication. Because dental prostheses have finite lifespans, an athlete injured in youth will require multiple crown and implant revisions over their lifetime, culminating in cumulative treatment expenses that exceed the initial cost of a professionally fabricated custom mouthguard by several orders of magnitude [3, 15].

From a public health and health-economics perspective, implementing mandatory custom mouthguard policies in organized sports represents a highly cost-effective preventive strategy [4, 9, 15]. Comparative cost-effectiveness models demonstrate that investing in custom-made mouthguards for high-risk athletic cohorts generates substantial savings by preventing emergency hospital visits and eliminating chronic dental restorative sequences [15]. When sports federations and educational institutions mandate custom-fitted mouthguards, the incidence of dental trauma drops dramatically, producing a positive economic return on investment for both families and insurance providers [4, 19].

4.4. Clinical Implementation, Education, and Athlete Compliance

Achieving widespread adoption of effective intraoral protection requires addressing athlete awareness, perception, and behavioral compliance [11, 20]. Despite clear clinical evidence establishing the superiority of Type III appliances, survey data indicate that a large proportion of young athletes continue to use over-the-counter "boil-and-bite" guards or forgo protection altogether due to misconceptions regarding comfort, cost, and actual injury risk [11].

Educational interventions targeting athletes, coaches, parents, and sports officials play a pivotal role in increasing compliance [11, 17]. Many young competitors report receiving little to no formal instruction on proper mouthguard selection, care, and replacement schedules [11]. Furthermore, peer influence and coach mandates heavily govern athlete behavior. In sports environments where coaches actively enforce mouthguard wear during both practice and competitive matches, compliance rates approach total adherence [4, 9, 19]. Conversely, when enforcement is lenient, athletes frequently abandon their guards due to minor discomfort or breathing friction [20].

Sports dentists and dental professionals must take a proactive leadership role in athletic community outreach [13, 14]. Dental consultations for young athletes should include routine screening of athletic participation, evaluation of existing intraoral appliances, and clear guidance on the physical limitations of over-the-counter guards. Furthermore, incorporating digital intraoral scanning workflows into routine clinical practice simplifies custom mouthguard fabrication, reducing chair time and turn-around periods, thereby making Type III appliances more accessible to amateur and youth sports clubs [10, 14].

5. Conclusion

Dentoalveolar trauma sustained during sports participation represents a major, preventable public health issue with long-term clinical and economic consequences. The protective efficacy of intraoral mouthguards is directly dependent on their structural design, material thickness, and retentive accuracy:

1. **Type I (Stock)** mouthguards provide inadequate biomechanical defense, severely compromise airway ventilation and speech, and should be excluded from athletic use.

2. **Type II ("Boil-and-Bite")** guards offer variable, unpredictable protection due to uncontrolled material thinning during manual molding, failing to guarantee necessary shock-absorption thresholds in high-impact scenarios.
3. **Type III (Custom-Made)** laminated mouthguards represent the definitive gold standard in sports dentistry. By providing a guaranteed, uniform thickness of 3.0 to 4.0 mm across critical impact zones, custom appliances maximize shock absorption, preserve normal respiratory airflow and speech articulation, and foster high athlete compliance.

Investing in professionally fabricated custom mouthguards yields significant long-term socio-economic benefits by eliminating the compounding financial costs associated with complex dental trauma rehabilitation. Sports governing bodies, healthcare providers, and coaching staff must collaborate to establish mandatory custom mouthguard protocols and promote educational initiatives across all contact sports disciplines.

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Methodology: AM

Software AM

Check: SP; AM

Formal analysis: KS

Investigation: KS

Resources: KS; SP

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